The author at the controls of the S-38
in flight to the Panama Canal

THE STORY OF THE WINGED-S

The Autobiography of

IGOR I. SIKORSKY

With Many Illustrations from the Author's Collection of Photographs

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FOREWORD

FLYING is now an important factor of life and progress. The existence of air-lines and military aviation, as well as of an established aeronautical industry and science, is taken for granted as a part of modern life. It is strange to realize that at the beginning of the present century all this was practically non-existent. All the flying in the world was represented by the separate efforts of a few individual pioneers, who were forcing the young art of flying ahead against tremendous odds and difficulties. The beginning of flying, and the quick progress from the first short hops, a few feet high, to the great flights across the oceans, and around the world, represents a very interesting story. The author of this book participated in this development from the early days. It is his desire to write down the impressions of the early pioneering days, and of the gradual development, describing mainly the work with which he himself was connected.

The Winged "S" is the emblem of Sikorsky aeroplanes, and its story starts with a tiny S-1 which could make only small jumps a few feet high, and ends with the huge S-42 flying Clippers of the Pan-American Airways, which surveyed and opened for peaceful air transportation the long routes across the Pacific and Northern Atlantic Oceans.

The title has been chosen as expressing the main subject to be discussed. It explains that the book deals not with the author's individual work, but with the ships, and with the efforts of various men who made them possible. The author has taken the liberty of mentioning a few facts of his own life, and his efforts in starting the work and pushing it ahead. The author considers himself not the individual creator, but mainly a leader of a fine and loyal group of competent aeronautical engineers, who were able to produce the work that is described in this book, and make the success of the flying Clippers under the Winged "S" possible.

The author wanted to make clear this fact, particularly with respect to the later period, contrasted with the early years, when most of the work, including complete engineering and test flying, was done by him personally.

Finally, the author wishes to express his sincere gratitude to Mr. Frank C. Dodd, on whose suggestion and encouragement this book has been written and published.

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I

A DREAM

DURING the year 1900, at the age of about eleven years, I had a wonderful dream. For several days I lived under the impression of that dream and have always remembered the details.

I saw myself walking along a narrow, luxuriously decorated passageway. On both sides were walnut doors, similar to the state-room doors of a steamer. The floor was covered with an attractive carpet. A spherical electric light from the ceiling produced a pleasant bluish illumination. Walking slowly, I felt a slight vibration under my feet and was not surprised to find that the feeling was different from that experienced on a steamer or in a railway train. I took this for granted, because in my dream I knew that I was on board a large flying ship in the air. Just as I reached the end of the corridor and opened a door to enter a decorated lounge, I woke up.

Everything was over. The palatial flying ship was only a beautiful creation of the imagination. At that age I had been told that man had never produced a successful flying machine and that it was considered impossible.

During the autumn of 1931, after a series of extensive test flights, Sikorsky Aircraft delivered to Pan-American

Airways the S-40, a four-engined flying boat, which was christened the "American Clipper." This plane was the first of a series of large flying Clipper ships that have been used successfully for long distance air travel to South America, and which eventually started the trans-Pacific air-line, and the trans-Atlantic air route.

I did a considerable amount of flying in this plane, but was usually so busy making observations, watching the instruments in the pilot's cabin, and solving various engineering problems, that I had little opportunity to get an impression of the flight as a passenger. Furthermore, all the preliminary flights were made with the structure bare, that is, without any interior arrangements, trimmings or seats. In this state the cabin was very noisy, and it was difficult to move about because the temporary floors were covered with a number of sandbags to represent the useful load. Finally, all tests were completed successfully and the ship returned to the factory for the installation of seats, tables, trimmings, carpets and other fittings.

Upon acceptance of the plane by Pan-American Airways, I was invited on a flight over New York with several members of the Board of Directors of that organization and a few other guests. The Pan-American pilots and crew were now in charge of the ship. I had no duties on board, and was able to enjoy the flight over New York, which was made partly above the clouds. We admired the scenery of the clouds against the setting sun, and the city which could be seen from time to time between the clouds.

On the way back to Bridgeport, the pilot throttled the engines and gradually brought the ship down to a lower altitude. The sun was already below the horizon,

and as the ship descended to a lower altitude, it became quite dark. The air was calm and the plane moved very smoothly, with the engines running at reduced power. I was in the front cabin at the time, and decided to see what was going on in the other cabins. While I was walking towards the smoking lounge, the cabin steward turned on the lights, and I stopped with a feeling of surprise. Some twenty feet ahead I saw the walnut trimmings and the elegant entrance to the smoking lounge. The bluish electric lights from the ceiling appeared bright and attractive. Usually I had been too busy to see the cabin with the lights on. Now looking at it for the first time under these conditions, I could well appreciate its fine appearance for it was much larger than on any other plane at that time. But I was surprised by another thought. I realized, at that very moment, that I had already seen all this a long time ago, the passageway, the bluish lights, the walnut trimmings on the walls and doors, and the feeling of smooth motion, and I tried to recall when and how I could have received such an impression, until finally I remembered the details of my dream of some thirty years before.

This book tells the story of how a dream of early youth finally became a reality.

II

MY FAMILY

I WAS born on May 25, 1889, in Kiev, situated in south-western Russia. I was the youngest in a family that already had three daughters and one son. My father was at that time a professor of psychology in the St. Vladimir University of Kiev, where he himself studied medicine and was graduated in 1869. His father was a clergyman with a large family, six sons and six daughters. My father had from his early years a pronounced interest in learning. He seldom participated in games with other children, preferring to take a book and find a quiet place for reading. Often the desired privacy was gained by climbing to the bell tower of the village church, where his father was the clergyman.

He was outstanding in his studies in his early years of school, later in the seminary, and finally in the University. After his graduation, he continued his studies and scientific work during all his life. He had chosen one of the most difficult and mysterious branches of medicine, psychology and mental diseases. As the years went by, he became a well recognized authority in this branch of medical science. He possessed remarkable ability to control and pacify an insane patient. Time and time again he was successful in treating cases which were considered difficult and

even hopeless. This required an ability to recognize the true character of a disease. As a result, my father was at times called in on complicated criminal cases as a medical expert. He was the author of several scientific books, some of which were translated into many foreign languages.

With all these activities, he had very little time left for recreation or even rest while in his own home town. Therefore, he usually made trips abroad, spending about five weeks every summer in some small, quiet place, usually in Germany or Austria. He always had his books, and even during these vacations he worked about half of every day, and during the remainder either took long walks or rested.

On one of these trips, in the summer of 1900, I went with him, and we spent about six weeks in the beautiful mountains of the German Tyrol. Every day we walked in the surrounding hills, and it was during this time that I learned from my father my first information about electricity, astronomy, and physics. It was perhaps my father's professional knowledge which enabled him to explain these subjects to me in such a way that I could easily understand them. These conversations planted in me an interest in these subjects which has always remained with me.

My father's life began under modest financial circumstances. When he left his native village and went to Kiev to enter the University, his parents were able to give him only fifteen roubles, and a samovar. Thus, while he studied in the University he had to earn his living by teaching. It was a difficult time. Besides serious study and working for a living, he had to walk long distances from the different

homes where he gave lessons, to the University, because the trolley fare was often outside his budget. In spite of this, he was successful in his studies, and was graduated in the year 1869, and two years later received his doctor's degree.

In this early career in medicine, he once received an unusual appointment, the story of which I liked very much to hear from him. It was during a heavy epidemic of cholera in Kiev. My father, at that time a young doctor, was appointed head of an emergency hospital which was organized to fight the epidemic. A group of buildings outside the city was assigned and necessary appropriations were obtained. My father quickly found and engaged several young and enthusiastic doctors to assist him in the work. In addition he needed attendants to run the hospital, but he quickly learned that they could not be hired. The population was panic-stricken, and no one wanted even to approach the frightful "cholera buildings." Yet, it was an emergency, and quick action was essential. My father went to the office of the Governor of the Province.

"Sir, I must have fifty men immediately for the hospital. I have been unable to hire them anywhere and consequently have come to you."

"My dear professor, I realize fully the importance of your request, but I am short-handed in every department and can get no further help."

"There are the prisoners, sir."

"The prisoners!"

"If you will grant me the authority to assure any men who volunteer for this service that their sentences will be shortened, I think I can recruit enough from

their ranks. And I think, too, that if they make good in this important work they will deserve any respite you may grant."

The Governor pondered this unusual request for some time, talking out the various aspects with my father.

At length he said: "Go ahead, I give you full authority and leave the details to your discretion."

Soon afterwards my father started his difficult work, virtually isolated from the rest of the world by a strict quarantine. He had with him three young assistants and a personnel composed of fifty former thieves and burglars. Those in this latter group were more frightened of their future duties than they were of facing a gun or knife.

My father began by getting his men together. After outlining in a general way the work ahead, he said simply:

"Not one of you will catch this disease if you will strictly and absolutely obey my orders."

A few days later, when everything was in readiness, the hospital started to function and was quickly filled up. It was a severe epidemic and the mortality was high. A few weeks went by, and my father's group learned to their astonishment that none of them had felt ill while the disease and death raged. From that time on their confidence in my father, and their obedience to his word, became unlimited. The hospital functioned for several months, the epidemic gradually died down, and not one man of his staff fell ill during the whole time. My father later said that he had seldom had such an obedient and well-disciplined group of men under his command as on this occasion.

As the years went by, my father continued his work as an active physician and specialist in mental diseases. He also continued his scientific research and became known as the author of several treatises, mostly on medical subjects. In 1884 he was offered positions as professor in some leading universities. He selected the University of Kiev in the province where he was born, and for the next twenty-six years he continued to lecture in the University where he himself had studied.

A large number of patients came to him, not only from Kiev, but from practically every part of the country. He was chosen an active, or honorary, member of several scientific societies and humanitarian organizations. In spite of having his time so completely occupied by these activities, he continued to write, mostly on scientific subjects. During his life over a hundred of his works were printed, among them the book, *The Soul of the Child*, which was translated into practically every language.

The continuous work necessitated a rest, and usually every year my father made a journey abroad for six or eight weeks. Even during this time he continued to study scientific subjects, but he also found time to visit galleries and libraries and to purchase more books. He collected during his lifetime an outstanding private library of some twelve thousand volumes, mainly on medical subjects. In accordance with his wishes, the library was donated to the University of Kiev after his death.

My father's working day was always filled. Even as a boy I could not recall seeing him idle, except about twice a day for short periods of some thirty

minutes when he usually took a walk in our large garden, which he himself had arranged according to his own taste, and in which he had personally planted many trees. From early in the morning he had lectures, visits to the hospitals, then he received patients and often visitors in connection with his many activities and duties. Only around eight o'clock did this extensive activity come to an end. Even after dinner and two glasses of strong tea, he usually spent another two or three hours alone with his scientific studies or with some literary work. His associates in the various branches of his activities often said that "Professor Sikorsky has thirty-six working hours a day." He surprised the men who worked with him by the remarkable uniformity of his frame of mind, the excellence of his speeches and lectures, by the remarkable accuracy of using words and expressions, and by the clarity of his intellect which never left him during his long life up to the last twelve hours. His time was occupied by hard work and his profession constantly brought him in contact with disturbing tragedies of life. In spite of this, the striking aspect of his personality was calmness, friendliness and idealism with respect to the higher values of life. The remarkable harmony of these characteristics, together with professional and scientific ability, made his personality very attractive, particularly to people in some moral distress. Many of them came to see him for advice and assistance.

I do not know much about the early years of my mother. She, too, received an education in a medical college, but the responsibilities of a mother did not permit her to continue her scientific work, in spite of

the interest she always had in medicine. Before my arrival in this world, she was much absorbed with the life and work of Leonardo da Vinci. This great Italian painter and scientist of the fifteenth century was probably the first man to study flying and to produce preliminary designs and sketches of wings. One of my earliest recollections was what my mother told me about Leonardo da Vinci and his attempts to design a flying machine. This was only one of the many things that I learned from her, but flying was so interesting to me that I never forgot those facts and the name, while I forgot most of the other things. I asked my parents, and many other people whom I considered competent, various questions about flying. At times I was told that flying had been proved impossible. I usually took such answers as a personal insult and started a bitter argument.

At the age of ten years, I was not particularly strong physically. Such efforts as running, or riding a bicycle, sometimes resulted in a hæmorrhage that was difficult to stop, and which caused my mother to worry. I too was disturbed by this, but chiefly because I thought it might spoil my chances of a flying career.

My earliest memories are connected with our large family, a big and rather prosperous house, and the well established position of my father in medical and scientific circles, as well as in our town in general. In the beginning, however, my father's position and earnings were extremely modest and our family life had to be arranged accordingly.

As the years went by, position and financial independence arrived, in spite of the fact that my father was never much concerned about either of them. It

all developed in accordance with a general rule which my father expressed as follows:

"A real man must do his work honestly without limiting his hours or efforts, and if he does this, he should not worry about compensation, because money and recognition will come of their own accord."

I also remember his adding that "hard work, whether physical or intellectual, for long periods, is not detrimental to the health, provided there are reasonable periods of rest." He warned us, however, that hard mental work, combined with worry, is dangerous and destructive to the health and abilities of a man.

As I mentioned before, my interest in various branches of natural science, and particularly mechanics and astronomy, started mainly as a result of the conversations I had with my father during our walks in the picturesque hills of the German Tyrol in the summer of 1900. My interest in astronomy, which began at that time, has remained with me ever since. During the succeeding years I had several hobbies. For a time I was making electrical batteries and also finally succeeded in producing a small electric motor. Time and time again I tried to make flying models. When I was about twelve years old I succeeded in making one of a helicopter, rubber-powered, which could rise in the air.

About a year later, I became interested in chemistry, purchased some materials, glass tubes, and so forth, and for a while was absorbed in making various experiments. At that time I found a propaganda leaflet which was distributed by radical socialists. In addition to the usual combination of

wild promises, as well as hatred towards anyone not in sympathy with their cause, it contained a very complete description of how to make a bomb by using a combination of materials that could be purchased at any drug store. I decided immediately that this was the real thing, even if the rest of the information was nonsense.

Obtaining the necessary materials, I started work and soon produced "stuff," which proved to work beautifully. I was careful enough to use only very small quantities at a time. To experiment with the explosive, I went into the garden as far from the house as possible. There I dug a hole, one or two feet deep, into which I placed a small bottle or paper tube containing the mixture, and then arranged to bring it in contact with a drop of acid, which resulted in a slight explosion, with fire and smoke, throwing some of the sand up into the air. My parents were not informed of this scientific work until one day my mother saw a workman who was apparently in a state of some excitement striding up to our house. She called my father from his study and together they met the man, who said he was the contractor in charge of the rebuilding of the house adjacent to our garden.

"I regret that I must make a complaint about the activities of your son in the garden."

My father turned inquiringly to my mother.

"Why, he has merely been tinkering with another of his mechanical contraptions," she said.

"Have you not heard some loud explosive noises, madam?" asked the contractor.

"Yes, but of course I thought they came from your work. You don't mean to tell me . . ."

"The 'contraption,' madam, is a bomb of some sort."

As my mother hastened towards the garden my father turned to the workman.

"I appreciate your telling us of this occurrence," he said. "But I cannot understand why you should complain of it."

"Why, sir," the man fairly exploded himself, "my men, no matter how I threaten them, are constantly leaving their work to watch these thrilling experiments."

In 1903 I entered the Naval Academy in Petrograd. I spent three years there, and completed the general course. While I liked the service, and particularly the active duties on board a vessel, yet a decision gradually developed in my mind that my real life's work was in the field of creative engineering. My thoughts and day-dreams often took me back to the flying machine. But facts which appeared well established by competent authorities indicated that this was impossible. It seemed that nature itself had a limitation and was able to send into the air creatures of not more than twenty or thirty pounds, while on the earth and in the water there were animals hundreds of times heavier. Therefore, it appeared that some other branch of practical engineering would be desirable. Having made this decision, I resigned in 1906 from the Naval Academy, where I was in good standing, in order to study engineering.

In 1906 the regular academic work in Russia was very much disturbed by the attempted revolution. Several of the engineering institutes were closed, so I decided to go abroad to continue my studies. Half

a year spent in Paris in the excellent school of Mr. Duvignau de Lanneau proved to be interesting and useful. By that time the situation in Russia had become better, studies were resumed in the universities, and it was possible for me to return and enter the Polytechnic Institute of Kiev in the fall of 1907. Although a reasonably successful student during my first academic year, I was not particularly interested in the theoretical studies and in higher mathematics, which appeared too remote from actual work. While at home, I still enjoyed my little workshop and laboratory where I built and experimented with various mechanical devices, among which was a steam-driven motor-cycle.

III
THE BEGINNING OF ACTUAL WORK AND THE TRIP TO PARIS

DURING the summer of 1908, I again went abroad with my father, spending about six weeks in Germany. Almost every day I read about the flights of Count Zeppelin in one of his early dirigibles. It was during that summer that I saw for the first time a reliable and accurate newspaper account of a successful flight made by one of the Wright brothers. This information impressed me considerably. The newspaper writer, an eyewitness of the flight, apparently did not realize the immense importance of this event. He wrote about a flying machine that rose gracefully into the air, making a flight of several minutes, and then landing not far from where the flight began. It surprised me not to see big editorials in the papers of the world declaring that the age-long dream of giving wings to man, a possibility which was predicted and expected by some and positively denied by others, finally had become a fact.

Personally I believed that some day a flying machine would be produced. Subconsciously, I had the feeling, even from early youth, that I, myself, would be connected with the development of a flying machine. However, engineering common sense, of which I had

some even at nineteen years of age, discouraged me from throwing all enthusiasm and efforts into this line of work. While my imagination and personal interest urged me to start such work, I realized that apparently competent men, with ability and money, had in the past made numerous attempts to fly and had failed. Moreover, nature had attempted, and also failed, to send even one or two hundred pounds into the air. Ostriches have wings and are generally built like birds, but cannot fly. But, with the Wrights, the situation changed. A flying machine was proved possible. A great reality appeared ready to fulfil the age-old dream of mankind.

I began assembling the various ideas which I had collected on this subject for several years. A flying machine rising directly from the ground by the action of a lifting propeller was most appealing to my imagination. Several years before I had succeeded in building a large and substantially heavy model, with two propellers of about thirty inches in diameter, that could rise in the air a few feet under its own power.

Frequently, during these years, my thoughts returned to various types of helicopters, and so during this summer vacation in 1908, I began in the room of a small hotel in Germany my first steady work in aeronautics. Only at a much later period was I able to realize how helpful had been my former training, achieved while I was experimenting, or even playing, with various mechanisms, building models, and so forth. I had already gained the knowledge that an inventor's idea is worth almost nothing unless supported by facts and figures. In order to collect at least some figures and make a preliminary check of the twin

screw helicopter which I had in mind at that time, I quickly produced in my room a few very rough devices which included a four foot air propeller, actuated by a heavy weight, and arranged in such a way that it was possible to measure the lifting force and the power required to drive it. The first results were encouraging. I could obtain a lifting force of more than eighty pounds per horse-power. I made a series of tests, and soon realized that such high figures could not be obtained on a full size machine, because it would require lifting screws of enormous size. I was convinced, however, that a practical helicopter could be produced even on the basis of the engines that were available at that time.

After my return to Kiev, I reproduced an improved testing equipment at home, and continued my research work, becoming more and more deeply interested in aviation. I obtained as many books on the subject as were available at that time. Towards the end of 1908, I became more or less familiar with the general facts and results obtained by the few men then connected with aviation who had succeeded in flying.

During December of 1908, a very important change took place in my plans. My elder sister, Olga, became interested in my work and offered me enough money to purchase an engine and other parts necessary for the construction of my helicopter. While I was overjoyed, I realized the seriousness of the decision ahead of me. A large sum of money would be spent, my studies would be retarded and criticism would be invited; but with all these drawbacks, the right decision was clear to me and I began making preparations to go to Paris in order to see the flying machines then in

existence, to purchase a motor and some other parts and start the construction of my own flying machine. To visit Paris appeared desirable, because, with the exception of the Wright brothers, most of the other important aeroplanes were in or near Paris at that time.

In January I left Kiev with the good wishes of my father and sister. Only much later did they tell me that some of our friends and relatives had considered it their duty to warn them against my trip. They thought it almost outrageous to permit a boy not yet twenty years old to interrupt his studies to go to Paris with a huge sum of money which, they predicted, would be spent not on machinery, but for totally different purposes. They were wrong, because at that time nothing existed for me except the idea of the flying machine which was now so close to realization.

My original plans called for a short trip, but upon my arrival in Paris, I soon realized that it would be desirable for me to remain for several months. The necessity of making a proper choice of a motor and ordering essential parts, and making a thorough study of the results already achieved in the art, could not be accomplished quickly.

Most interesting to me were my first visits to the flying fields. I was familiar with the main types of early aircraft from pictures I had seen, and finally I was able to approach these strange-looking machines and could watch with deep interest the work that was being done during the long periods of cranking the motors by turning the propellers, a procedure which sometimes resulted in getting the motors started. A few mechanics would usually hold the machine by the

tail, giving the pilot an opportunity to adjust the motor. Standing close, one could smell the smoke of the running engine. Even now the smoke of burning castor-oil is connected with sweet memories of those early years.

Finally, the pilot would raise his hand, the machine would be released and would start to run along the ground. This meant sometimes, but not always, that the plane would leave the ground, reaching a couple of feet of altitude, and then making a long jump across the field. This was the kind of scene I witnessed once in a while after spending a considerable number of hours visiting the flying fields of Issy de Moulineaux and Juvisy, near Paris. Only the Wrights, Farman, Bleriot, and a very few other leaders of this epoch, were able to get into the air when they wanted to, and stay up for any length of time. I had no chance of seeing any of the big men flying during that visit, but even the small jumps which I saw produced a deep, unforgettable impression. The dream of my life, which I believe had been the dream of mankind for thousands of years, as can be seen from pictures and legends and songs of most modern and ancient peoples, became a reality before my own eyes, and I had the good fortune to join in this work.

Within a week after my arrival in Paris, I visited Captain Ferber, who was one of the outstanding pioneers of early aviation. He was following the glider movement, after the example of another outstanding man, Otto Lilienthal. Captain Ferber was enthusiastically devoted to practically all branches of the new art. He started by working with gliders and continued with designing and piloting a plane of his

own type. He made numerous tests, developed research methods, participated in early theoretical work in aerodynamics, and was already the author of some books on aviation. I spent a most interesting hour discussing problems with Captain Ferber.

"Do not waste your time on a helicopter," he advised me again and again, kindly but firmly. "The aeroplane will be far more valuable."

He supplied me with information on the new branch of engineering about which so little was known at this time. Among his many expressions, one, to my mind, showed particularly well the character of the work of that pioneering period.

"To invent a flying machine is nothing; to build it is little; to make it fly is everything."

In French the last of the three phrases would read: "*L'essayer c'est tout,*" which means "to test it out is everything." However, knowing the ideas of Captain Ferber on this subject and the slang of French aerodromes of that epoch, I am convinced that my translation gives the correct meaning of this expression.

"Why don't you enter the new aeronautics school?" he suggested.

"I'll do it immediately."

Captain Ferber was one of the instructors of the recently organized school. I promptly filed my application, paid a modest fee and was admitted. It was an extraordinary school at that time—no examinations, no diplomas, not even a definite programme. I would compare its curriculum to the schools of the ancient philosophers. Here was a group of men eager to learn something about a subject vitally interesting to them, about which at that time there existed no science, no

reliable books and very little practical information. There were a few men, including Captain Ferber, who did know something and who were willing to talk about it. There were no regular courses, but the students would assemble, usually in one of the hangars in Juvisy, gather round one of the teachers and listen to whatever he would be willing to divulge, and later engage in discussions. I did not learn much during the few weeks in this school, and I had not expected to, but I got substantially what I wanted. The school provided a reason for my presence at the airport; it permitted me to familiarize myself with general ideas, methods, and materials, and put me in touch with men actively engaged in aviation work who could give me information and advice. Of course, the information was often of a very doubtful nature, but I already realized that even this could sometimes be used to advantage.

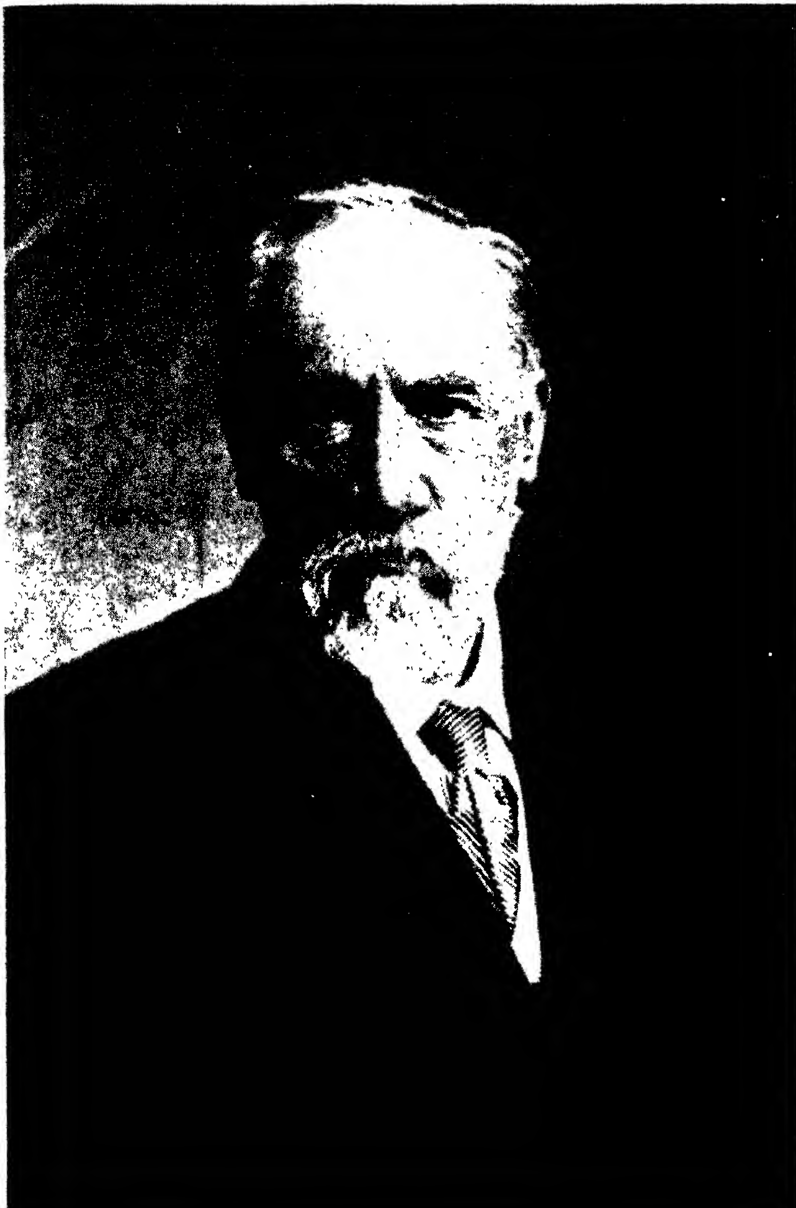
The important thing for me was to make a correct decision on the type of motor to use. I had already seen enough of the troubles experienced with various engines, which quite often were indisposed to get started in spite of frantic efforts and strong language used by the mechanics. If such a thing could happen with the engine factory just round the corner, I was worried about the greater difficulties I might have in far-away Russia, where I would not be able to find any experienced assistance in case of trouble. I asked one of the aviators, who was considered competent partly because he had already "broken plenty of wood on the field," which he thought was the best aircraft engine available. In aviation language of that time "to break wood" meant to "crack a plane."

"There are no 'best' motors; none of them is any good."

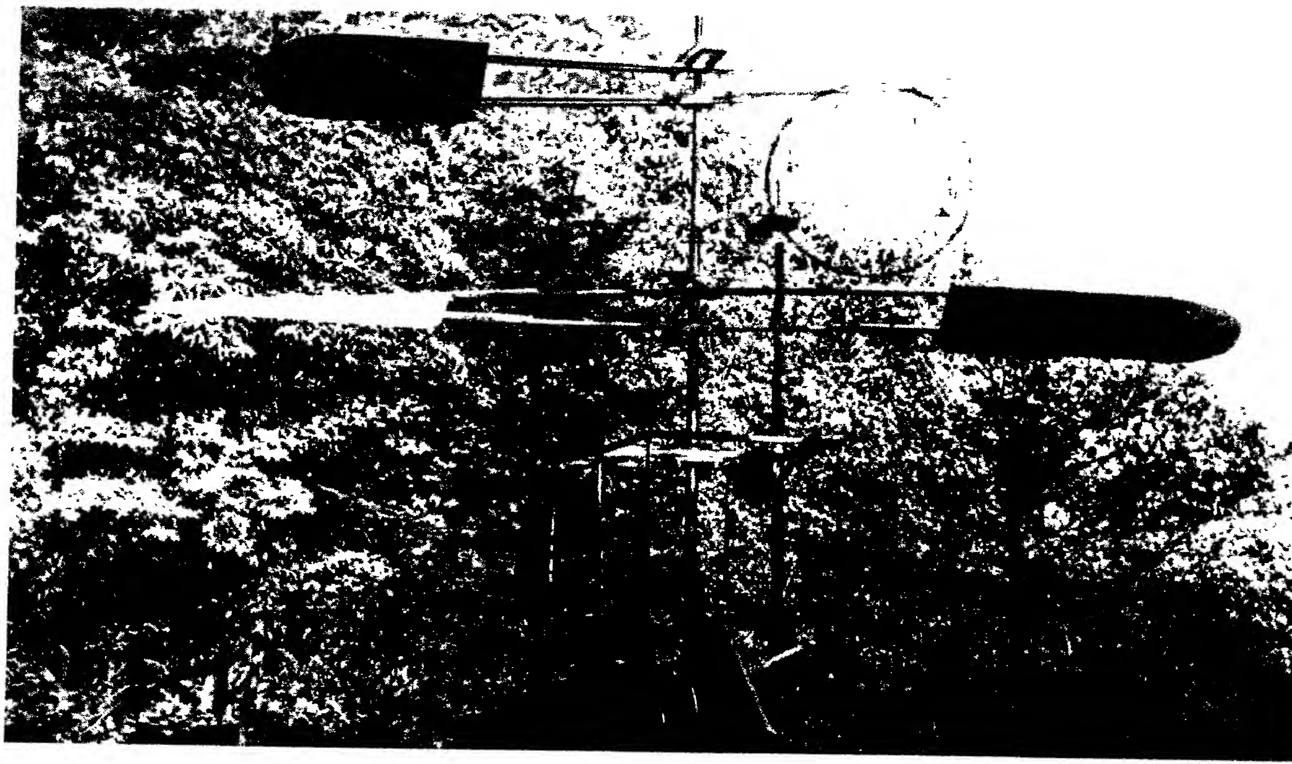
I was not going to let him get away so easily with such an answer, and said, "Well, which one do you think is less bad than the rest?" and in the discussion which followed I learnt a few useful facts.

Gradually, I grew familiar with flying equipment, motors, sources of information and supply, and became at home in this most peculiar new passion of mankind. It is doubtful if a better word could be found, because to call aviation of that period an industry, or a method of travel, would have been premature. Flying from one place to another was practically unknown. Twenty-five thousand francs were still available as the prize for the first person to fly a heavier-than-air machine across the English Channel, a distance of some twenty-two miles. On the flying fields it was possible, once in a while with good luck, to see a plane make a few circles round the field at an altitude seldom higher than thirty or fifty feet. This was an outstanding exception, which only a few of the big men could accomplish under favourable conditions. The Wright brothers were already able to fly well even in this epoch, but I had no chance to see a Wright plane until 1910.

The majority of fliers near Paris could only "rouler," which means run on their planes along the runway, making small jumps once in a while. Even this was not bad, but there were a large number of machines and planes built by various inventors inspired by wild and hopeless ideas. Many of these could not even move along the field, and would have been considered funny if there had not been real



Professor I. A. Sikorsky



The first helicopter in the Summer of 1909

tragedies of discouragement behind most of them. In many cases it was easy to see a similarity to a previous design which had already been proved a failure. Yet with a stubborn persistence, the next inventor would use all his energy, spend all his money, and often borrow to the limit in order to build a machine. And then fail as hopelessly as his predecessor.

Often after an interesting day filled with new impressions and not feeling any fatigue, I sat alone in my hotel room or in a café on the Grand Boulevards of Paris, thinking that I had started to work in a field where the majority failed and few succeeded. This was a troublesome idea, but there was also the comforting realization that nearly all discoveries were preceded by numerous failures. What was necessary was the study of the prior art and correct general decisions, the reduction to a minimum of incorrect assumptions and plenty of hard work. The prize was the ability to fly and see the earth from above, the realization of a great ambition.

As time went on, I became well acquainted with the various aeronautical engines, having spent much time in the few factories, and finally made a choice of an engine. It was the product of a small shop situated at that time in Asniers sur Seine, on the outskirts of Paris. Some thirty-five men represented the whole force, together with the owner and designer of the engine, Mr. Alexander Anzani, who was a sportsman and builder of racing motor-cycles. The Anzani aeroplane motor was by far the simplest engine available. It was a direct development of a motor-cycle engine with three, instead of the conventional two, cylinders. It appeared to have the smallest number of parts, was

easy to start and to maintain. I ordered a motor, and frequently visited the shop during the assembly and test of the engine, which was a three-cylinder 25 h.p. type.

It was at the factory, while awaiting delivery of the engine, that I met Louis Bleriot, who had also placed an order for a similar engine. A few months later he crossed the English Channel in his small monoplane, powered with a 25 h.p. Anzani motor, thereby reaping well-deserved fame and fortune for himself, as well as for the engine which had carried him safely across.

A few other parts of the flying machine were ordered, and made in accordance with my sketches, and early in May I returned to Kiev, and started the construction of my first helicopter.

Captain Ferber and the well-known scientist-designer of early propellers, Drjevietzky, strongly advised me against spending my time and effort on a helicopter. Drjevietzky even wrote an article for one of the magazines entitled, "The Wrong Way," in which he explained the hopelessness of the helicopter proposition. Both of them may have been right, at least at that time, but I was so much attached and interested in my first attempt that I did not wish to drop the matter and decided to work on it until it materialized.

IV

THE FIRST HELICOPTER

THE four months spent in Paris in the cradle of European aviation proved to be very helpful. In addition to the engine, materials, books and magazines, I brought back a good store of information. I had obtained valuable experience from the few successful attempts and the numerous failures that I had seen. However, I learned very little about the flying machine itself. I saw aeroplanes and I, myself, was working on a helicopter, and I got hold of some fundamental ideas on methods of creative development work in a new branch of engineering, where reliable information was scarce. This being the case, it was necessary to rely on intuition, which at an early period is often the major source of information in inventive engineering work. Intuition or inspiration, which guides an inventor towards achieving technical possibilities that are not yet known, are liable to evolve into day-dreaming, in which case the work has a good chance of becoming a failure. Therefore, while some part of inventive activities may well be compared to the work of an artist or even a poet, yet to achieve his purpose, the pioneer designer must keep all his ideas under strict control and must reduce them as much as possible to proven facts and measured or calculated figures, so that every idea will be verified no matter

how excellent and correct it may appear. Another important fact learned was the necessity to design the new flying machine flexibly, so as to make corrections and changes easily, since difficulties and troubles in a new machine may develop where they are least expected.

At the beginning of May, 1909, not yet twenty years old, with a few ideas, no experience, some caution and, of course, with plenty of enthusiasm, I started the construction of my first flying machine. At that time, I had no mechanics or workmen to assist me. I had brought back from Paris the transmission and shafts which were built there in accordance with my drawings. I ordered other parts and materials from Kiev and did all the assembly work myself. It was really a wonderful feeling to see how the strange-looking machine which I had been dreaming and thinking about was gradually taking shape in one of the rooms in our house, which had been transformed into a shop.

The helicopter had a wooden frame similar to a large rectangular box, with a 25 h.p. Anzani engine on one side and the proposed seat or platform for the operator on the other. In the centre of the frame was the transmission box. A large wooden pulley was connected by a four-inch-wide belt to a smaller pulley on the motor. Two concentric vertical tubular shafts were connected with the transmission box and were guided by an upper bearing at the top of the frame. On each of the shafts there was mounted a two-bladed lifting propeller, the upper one having a diameter of about fifteen feet, and the lower one sixteen and a half feet. They rotated in opposite directions at the rate

of 160 r.p.m. The blades were supported by piano wires which were connected to two rings fixed to each shaft above and below each propeller. By changing the length of the wires by the use of turnbuckles, it was possible to adjust the pitch of the lifting propellers. On the basis of results obtained with small models, I intended to produce a forward motion and to regulate the speed by inclining the machine forward. This I expected to obtain by the use of control surfaces that were to be placed below the outer part of the lifting propellers. I intended to adjust them so as to obtain the desired results from the air pressure created by the combined action of the slipstream and of the forward motion. Control surfaces were not built for this machine because it appeared desirable first to make a test of the proper operation of all mechanisms and to check the lifting capacity.

During the month of July, the helicopter was completed and the tests were started. Various minor troubles developed which required some adjustments and changes. At first, it became necessary to fix the transmission because the belt kept slipping. When this was adjusted and I could increase somewhat the power transmitted to the propellers, the main shafts started to shake so badly that it was immediately necessary to slow down the engine. The propeller blades were then dismounted and carefully adjusted for weight, and reassembled. The machine was again tested and still proved to be unsatisfactory.

It was possible now to exceed the speed of rotation which had been critical before, but every time at a certain moment the shaking would start again. Once started, it would quickly become dangerously violent,

necessitating an immediate stopping of the engine. During these tests it was impossible to release more than one-half of the power and the machine remained firmly on the ground. Eventually I decided to make a study with the machine not in operation by climbing on the top of the gondola and finally on the root of the lower propeller. I succeeded in shaking the inner shaft with my hand to reproduce the "trouble." It was easy to count the amplitude and to find out that it happened slightly less than one hundred and twenty times per minute. To remedy this fault, I took a piece of hard wood about four feet long and fitted it exactly on the interior cross-sections of the shaft of the upper propeller. I then hammered it gradually into the steel tube, testing the frequency of oscillation from time to time. After the end of the wood passed the upper bearing of the propeller shaft, the frequency of oscillation started to increase. I continued to hammer it down until the oscillation exceeded one hundred and seventy-five per minute, because the maximum normal r.p.m. of the propellers was 160 r.p.m.

The next test with power showed a complete cure of the vibrations. Gradually I could reach the former critical number of revolutions and everything worked smoothly. During these tests I used to stand near the end of the frame, opposite the engine, with my hands on the throttle and on the switch. There was little wind at that point because the inner part of the propellers was not covered and the blades were circling outside, but below the periphery there was apparently a strong blast of air thrown down, for I could see the dust and leaves blown in all directions from the

machine. I gave more gas and nearly lost the machine, because immediately the helicopter started to turn over towards the heavier side where the engine was located. I jumped on the frame and throttled the engine and the machine returned to normal position. This negligible incident made me very happy. For the first time I could feel the power of the machine and, as I thought, the helicopter showed a readiness to go into the air. I can remember very precisely my impression that when I stood on the frame of the machine which was about one foot above the ground, while the other end was still on the ground, that the end on which I was standing did not fall but was gradually pushed downwards against some force which was supporting it.

Another check was made for weight distribution, and a small platform attached in the proper place on which to stand during the tests in order to balance the weight of the motor. During the next test, when still more power was applied, the whole frame, while still on the ground, started to rotate around the main axle. It was not violent and I could stand on the platform holding fast to the frame. This was simple to explain and also to adjust. By releasing some of the wires which supported the propeller blades and tightening the others, it was possible to adjust the pitch of the propellers in such a way as to equalize the torque, or rotational force. When this was done, the "waltzing" of the helicopter nearly ceased, but it still remained extremely sensitive and usually a small amount of rotation of the frame with the motor and observer always remained when tests were made with nearly full power on. It was pleasant and encouraging to

feel the machine slowly turning and displacing itself gradually along the ground, assisted by the vibrations of the engine and transmission. It was easy to feel that the supporting propellers were already carrying a large part of the weight of the helicopter, including the fuel and the "pilot."

However, two important facts of a different nature also gradually became evident. It was clear that this machine would not be able to lift itself with a man on board. Further it would hardly be possible to control the machine by the means originally designed, which consisted of a few auxiliary surfaces situated in the stream of the propellers. While a direct test of this had not yet been made, I could see that the wind created by the huge propellers was rather gentle, while the forces necessary to maintain the proper position proved to be considerable. Besides this incident, the machine once started to turn over when a gust of wind came while the propellers were working at nearly full speed. A quick throttling down prevented trouble, but the necessity of a power control to act under all conditions became evident.

The tests and experimental work, however, proved to be very interesting and instructive. I learned much by working from early morning until late in the night and by gradually eliminating the few major, and multitude of minor, troubles. This was all excellent training. By fixing the troubles, reinforcing the parts which would not stand up, adjusting the various mechanisms which would permit the whole machine to run for several minutes at a time at full power, I could learn what could not be obtained from books. The practical experience gained was very valuable, but

with knowledge came the realization that the first helicopter would never get me in the air.

Having arrived at this conclusion, I decided to change the programme of tests in order to obtain more accurate information on the action of the machine. Having lost hope of flying this particular contraption, I arranged a large scale, fixed the helicopter firmly to one side of the scale and loaded it with ballast so as to prevent the machine from turning over under any circumstances. This also excluded the rotation of the gondola which was the usual consequence of most previous tests made at full power. This arrangement permitted testing the machine under any amount of power while making all necessary observations and measurements. Mechanically it functioned at that period satisfactorily, and very few adjustments or repairs were needed even after reasonably long runs.

The scale enabled me to measure the lifting force of the propellers under various conditions. The highest lift figure was about 357 pounds; the weight of the helicopter empty was about 100 pounds in excess of that figure. It appeared certain that a more refined design of the lifting propellers, with larger diameter and a more elaborate wing section of the blades, would increase the lifting force substantially. I felt, however, that the machine could never be improved to the extent of being able to take off with a man on board and, therefore, having completed a series of runs with various combinations of propeller blades, I decided early in October, 1909, to discontinue the tests, and to disassemble my first flying machine.

This machine was a failure to the extent that it could not fly. In other respects it was a very im-

portant and necessary stepping stone. As mentioned before, it furnished a substantial amount of experience and engineering information which in that epoch could not have been secured by any other means. Of even greater importance were some general conclusions which resulted from contact with realities after a period of planning, acquiring ideas, and at times even day-dreaming. I realized that success at that time could not be achieved by producing one particular flying machine. What appeared to be needed was a decision to gather much more knowledge and experience covering various phases of the new art, and continuing to work hard, readjusting the programme if necessary. Although plans for a new and improved helicopter were well under way at that time, I decided not to start the construction for a few months, and in the meanwhile to do other work and to visit the flying fields in Paris again.

While working on the disassembly of the helicopter and making arrangements for the trip abroad, I again turned with much energy and interest to the construction of flying models. It was a comforting discovery to find that they were much more successful than before.

During the short trip to Paris, I was able for the first time to see aeroplanes in actual flight and this thrilled me greatly. The sight of Count Delambert in a Wright biplane several hundred feet in the air produced a most wonderful impression which I shall never forget. While developing plans for an improved helicopter, I became more and more interested in aeroplanes.

A short time later a few sketches of planes appeared

in my books and work was started in this new line. As a result of the failure of my first helicopter, I decided that a more gradual approach to the aeroplane would be desirable and therefore made plans for the construction during the winter of two air-driven sleighs. I intended to design and build propellers for the sleighs, and later in the spring install the motors used in the next flying machine. I expected to gain experience in the design and construction of propellers, as well as to study the practical operation of an aircraft power plant under conditions similar to an aeroplane installation.

I returned home from Paris with additional information, some aircraft hardware, and two more Anzani motors, a new 25 h.p. motor for the second helicopter, and a 15 h.p. motor for the air-driven sleigh. I already considered the construction of a small aeroplane with one of these motors. Using such information as I could obtain and relying on guess and common sense, I designed and calculated the propellers for the sleigh. I ordered the first one from the carpenter who usually fixed the broken furniture in our home. He returned in a few days with a white pine propeller, which he had varnished and for which he charged me five roubles. I got a great thrill when I had my first ride in the newly built sleigh powered with a 15 h.p. Anzani motor and this propeller. In good weather, the ride in the propeller-driven sleigh was very pleasant, particularly in the larger sleigh with the 25 h.p. Anzani motor.

Swiftly gliding along on the sparkling surface of the snow was thrilling, but I received a still greater sensation from the feeling that this was one more step

in the right direction. The installation and the running of the engines taught me a lot. After the first propeller, which lasted a very short time, others were made of walnut and mahogany which proved more serviceable.

In February, 1910, I dismounted the motors from the two sleighs and started to build my second helicopter and also my first aeroplane, the S-1. It is needless to say that in addition to the practical work which was done, every effort was made to study and to secure as much theoretical information as possible. I felt considerably better prepared for the job than I had been the year before at the time the first helicopter was started. However, the more I learned the more I realized the great difficulties that were still ahead.

Early in the spring of 1910, the second helicopter was completed. It was a graceful, although strange-looking machine. With its slender propellers in motion, it resembled a huge butterfly. Results were somewhat better and the helicopter lifted almost its whole weight of about 400 pounds. The first tests indicated that it could not carry the additional weight of an operator. I realized that with more power, or with further refinement of the lifting propellers, it could probably be accomplished. But by feeling rather than by exact knowledge, I came to the conclusion that tangible success along this line was by no means round the corner. While the work on the helicopter was continued, I hurried the completion of the S-1 aeroplane and by the middle of April, 1910, I had it on the field ready for tests.

V

THE FIRST AEROPLANE

THE S-1 was a small, light, pusher biplane powered with a 15 h.p. Anzani motor. The aerodynamics and the balance of this plane were chiefly based on guesswork. The structural strength was based on some primitive analysis which was ascertained by proof tests of main parts of the complete aeroplane. After a check of the engine was made on the ground, the plane was ready for my first attempt to fly.

With a great thrill, combined with the realization of the importance of the moment, I climbed into the pilot's seat and turning round towards one of my assistants, I said, "Off," and the mechanic started to turn over the engine in order to prime it. A moment later, he shouted, "Ready!" I replied by the wonderful, magic word,

"Contact!"

He turned the propeller, and after a few more "contacts" the engine started. As was usual at that time, a few of the men held the plane by the tail and wings, while I gradually opened the throttle about half-way. The slight trembling of the machine gave me the impression that it was ready to rush ahead, while the noise of the motor sounded like heavenly music. I looked round, checked the controls once more by moving the stick and pedals, and raising my

hand, gave the signal to release the plane.

Nothing exciting happened that day, however. After being released the S-1 commenced to move and accelerate, but a few seconds later it started to make a quick turn and I had to throttle the engine back in order not to damage the plane. I repeated the attempt again and again, but every time the plane reached a speed of fifteen to twenty miles per hour, it would again start turning to the right or left, forcing me to slow down the engine. Apparently the rudder was not effective. During the next few days I installed a new rudder, then still another one, but the same trouble persisted. I gradually learned that the source of difficulty was more the fault of the pilot than the rudder. The light, underpowered machine, mounted on reinforced bicycle wheels, was very sensitive to the uneven ground and required control, particularly while moving slowly. I soon discovered that to prevent the tendency of the machine to turn, it was necessary to jerk the rudder in the opposite direction at the very beginning of the turn.

A few more days of such training and I was able to run the machine across the whole field at twenty-five to thirty miles per hour, keeping it under reasonable directional control. The next step, learning to lift the tail and to run with the wings horizontal, was achieved quickly. I found that it was easier to guide the machine while running the small 15 h.p. nearly wide open with the tail up. Having accomplished this, I resumed my attempts to get into the air. Timidly and carefully at first, I permitted the plane to accelerate with the tail up and then pulled the stick and lowered the tail, expecting every moment to find

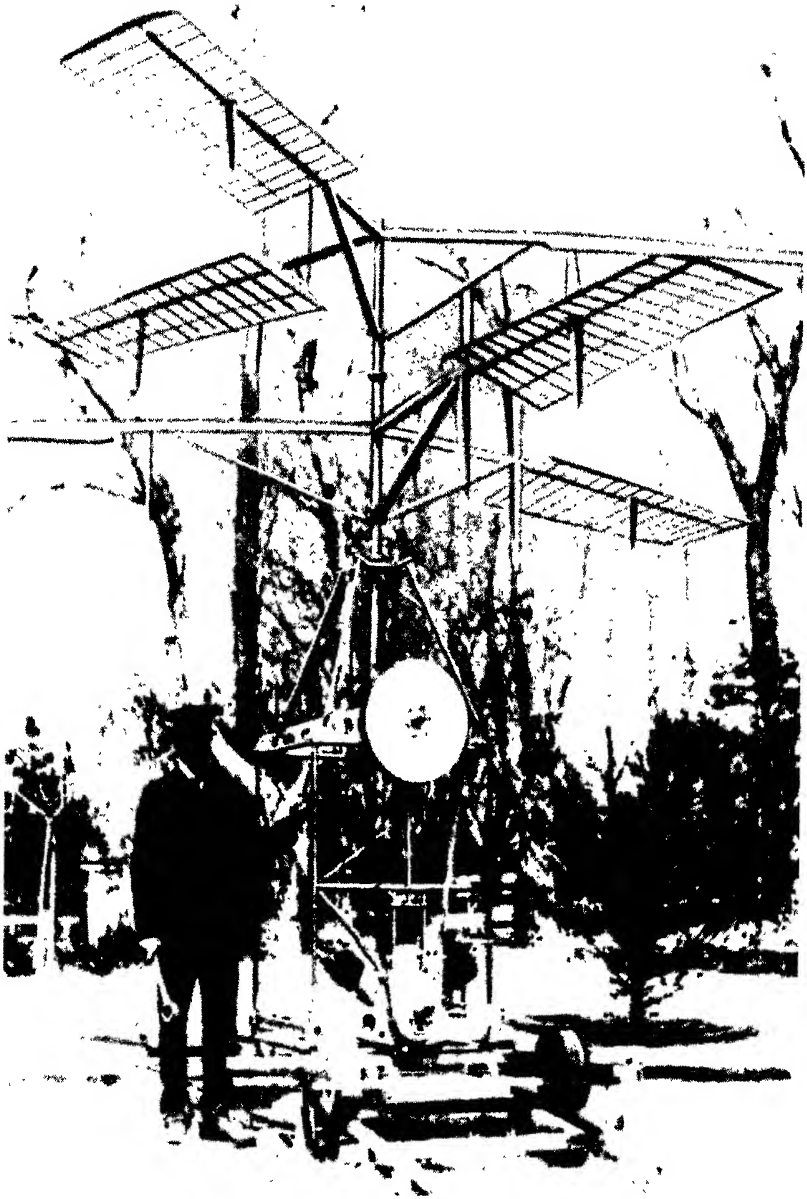
myself in the air. This, however, did not happen. I repeated these attempts time and time again. By now, being substantially familiar with the small aeroplane, I could make it do about everything of which it was capable. With the engine wide open, I permitted the machine to make as much speed as it could while running on the ground. I kept the tail at various heights, trying to feel out a position which would give the least resistance and allow more speed. Then, at a given moment, I would lower the tail, but still nothing happened. The plane would reach a speed of some thirty-five miles per hour, and then slow down after the tail was lowered.

Even though three weeks had gone by since the first attempts were made, I realized that the time was by no means lost. I had familiarized myself with the plane. I could run it to any part of the field and upon reaching the end, I would throttle the engine until the plane would move along slowly. Then I would jump off, and hold one wing until the plane turned in the desired direction; then I would climb back on the seat, open the throttle and run in any direction with the plane under control and the tail up in the air. This, of course, was fine. The only trouble was that I, myself, with the plane, was still firmly on the ground. I continued the attempt to get the S-1 into the air. While at home I had experimented further with helicopter No. 2, but the hope that one of the two machines would fly gradually disappeared.

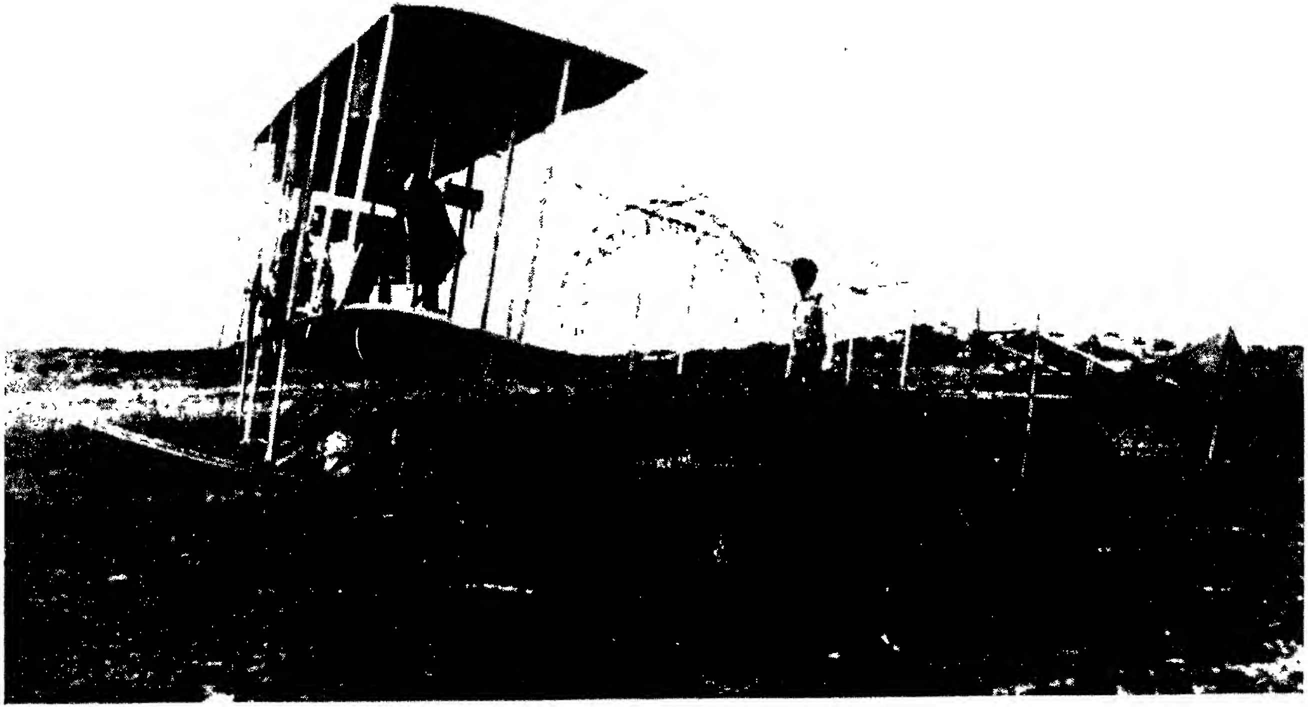
Early in May, 1910, I wheeled the S-1 out of the hangar on a windy day. I taxied slowly to the end of the field, turned against the wind and opened the engine. I was able to raise the tail immediately and

after a few hundred feet run, I lowered the tail and the S-1 rose in the air, but in a few seconds it settled down before I could do anything with the controls. The S-1 had actually been in the air on that occasion. My enthusiasm was greatly cooled, however, by the fact that I could not repeat the jump in spite of several attempts. A gust of wind which came at that moment must have lifted the small plane some two or three feet. Even this modest performance, alas, could not have been accomplished by the S-1 under its own power. I taxied back to the hangar since there was apparently no use in making further attempts to get the S-1 into the air. It did not have enough power, that was evident.

Helicopter No. 2 could still furnish what at that time was called "scientific information," but, like the S-1, it would not get me off the ground. I suspended all tests for a few days, feeling the necessity of revising the programme of work. I had good reason to be somewhat disturbed, because a year and a half of hard work had gone by, and some harm had been done to my studies at the Institute. Moreover, a substantial amount of my family's money, far in excess of what I had thought would be sufficient, was spent. Yet there were no tangible results. The situation presented a problem. As the future eventually proved, however, it was solved correctly. I decided to disassemble both machines. The work on the helicopter was to be discontinued indefinitely. I believed then, as I do now, that a practical helicopter can be created. But I realized that the amount of time, money, and facilities necessary to solve the helicopter problem was more than I had at my disposal. Therefore, I decided,



The second helicopter ready for testing in the Spring of 1910



The S-2 in the Summer of 1910

it would be better to discontinue work on the helicopter and concentrate all my time and efforts on the aeroplane.

The few weeks spent in taxi-ing and forcing the S-1 into the air were by no means lost, because much was learned during these attempts. The information, particularly with respect to the manœuvring of the plane on the ground, the action of the controls, and so forth, which I had learned from books and magazines, now became real facts which I could understand and feel. I had also gained some practical ideas for improving the S-1, so I again resumed the work and hurried the construction of a new aeroplane. Using the wing group from the S-1, I built a new centre part, and made it a tractor plane. I installed the 25 h.p. Anzani which had been taken off the helicopter. The tail was changed, and the new one consisted of a stabilizer with two fins forming end plates. On their trailing edges were mounted rudders. The landing gear was reinforced and a new pilot's seat was installed behind the motor. A little more than three weeks of continuous hard work, which started early in the morning and continued until late at night, with only short intervals for meals, were spent to complete the new plane.

On June 2nd, the S-2 was wheeled out of the hangar. During the motor test, when I felt the force of the propeller stream and saw three of my associates having a difficult time holding the plane from running ahead, I realized that there was much more power here than in the S-1. There was a distinct feeling that the S-2 could fly. I did some taxi-ing in order to check the plane, and found that the ship accelerated much faster

and also obeyed the controls better. Minor adjustments to the plane and the power plant took the rest of the day and evening. Late on the night of June 2, 1910, we were sitting round the fire on the field near the hangar, looking at the S-2 which appeared ready and able to fly. The few men who were there that night had participated in the construction of my flying machine and had assisted me during the tests. Two professional carpenters and one plumber, who was enthusiastically learning about the aviation engine, received modest salaries. Then there were usually two of my personal friends, students of the Institute of Technology, and one or two other men. This latter group received no salary but worked because of their interest for aviation.

The pasture field on which I built the hangar was situated about two miles from the outskirts of Kiev. There was no place to eat in the neighbourhood, and sometimes during the middle of the day we received food from home. A man who worked in my father's garden brought the dinner to the field, and during rainy weather we were certain of a hot meal because the man would have to come by trolley, whereas in good weather the dinner would be late and cold because the old man would stop in several saloons for "refuelling." After hours of work in the fresh air, even the cold dinner was enthusiastically welcomed. The whole group, during dinner, discussed various aviation subjects. In the evening, after work or after the tests, quite frequently the group would get together round the fire, prepare some tea, talk over the results of the day, and settle as well various general questions about aviation.

VI

THE FIRST FLIGHT

IN the morning of the next day, June 3, 1910, on the way to the field, we made plans for the first test of the S-2. The cloudiness and very light wind appeared favourable. The S-2 was wheeled out of the hangar, I checked the controls, climbed into the seat behind the motor, and shouted,

"Contact."

The engine was quickly started. While three men held the plane, I gradually opened the throttle, and a few moments later the good sound of the motors, the propeller blast, and the smell of burned castor-oil told me that it was time to try.

I gave the signal, and the plane was released. The S-2 had a much better acceleration. From the very first moment I could feel that the stronger propeller blast made the control more effective and the tail went up at once. I had no tachometer, not a single instrument, in the S-2. A few seconds later, feeling that the speed was already well in excess of what the previous plane could ever do, I gradually started to move the stick back. A moment later, I was in the air. All my attention was concentrated on the controls. Having never before been in the air, even as a passenger, I had to learn quickly the necessary movements which were

familiar in imagination but not yet in reality. By delicately pushing or pulling the stick I could hold the plane at two to four feet of altitude for a time, which appeared quite long to me, as well as to the witnesses of this first flight.

Finally, the plane, for some reason, settled down. Feeling that the wheels were again on firm ground, I cut the ignition. A few moments later, the men who witnessed this flight crowded round the ship far more excited than I was myself. This was the first time that any person then present on the field had seen a flying machine in the air and their excitement and enthusiasm were perhaps far in excess of what this very modest performance deserved. The flight was about two hundred yards long at an altitude of two to four feet, and lasted about twelve seconds. I made no more tests that day. With reverence, and almost with tenderness, my boys put the S-2 back in the hangar.

Seriously feeling the lack of instruction in my piloting, as well as in design, I tried at least not to lose any data that would be useful. Therefore, this flight was followed by a discussion during which, with the help of the witnesses, a reasonable picture was evolved of how the plane took off, how it behaved in flight, and so forth, to check my own impressions.

The next day I rolled the plane out with much more confidence and decided to fly higher and farther; if possible, across the whole field. I took off and continued to hold the stick slightly back. To my delight, the plane arose in the air to some six or eight feet. Next, however, to my surprise, the ship started to settle down and landed rather heavily although without damage. I repeated this attempt a few times, but

to my disappointment, the results were no better. The plane would take off every time, but then it would settle down no matter what I did with the controls. I tried to push the stick, and this would only cause it to descend more quickly. It would usually reach no more than six to ten feet of altitude so that the duration of each of these hops was even shorter than that of the first flight. Apparently there was still not enough power, or, possibly, something else was wrong.

A few days later I decided to have the S-2 held for a longer time after starting the engine and to adjust it for maximum power. With the tail up and the wings nearly horizontal, I ran the plane longer than usual, permitting it to gain all the speed it could. Then I pulled the stick back. The rise was quicker and much higher than ever before. My assistants said later that it was very high, as high as a four-story building. Then again it started to come down and continued to lose altitude in spite of everything I tried to do with the elevator. With its motor working, the plane landed in a normal position but very heavily. The landing gear collapsed and the S-2 turned over, breaking the propeller and suffering other damages. In spite of that, I felt quite happy and even proud. I was delighted with the "high" flight, and even the slight crash was a normal event in aviation at that time. I decided not only to repair, but also to improve the plane.

During the next three weeks the plane was repaired, the fabric covering tightened and improved and a few other refinements were incorporated. On June 29th, it was again ready for flight. I took off as usual, climbed to ten or fifteen feet, and tried to hold

the plane at that height. To my great satisfaction, it did not settle down but obeyed the controls and continued to fly nicely. Gently, I tried the elevator and ailerons. The plane responded well. For the first time I stayed in the air as long as I wanted to, and finally landed on the other end of the field. The flight was repeated. Again it was nice and smooth about one-half minute long from one end of the field to the other. This was finally real flying, and it made me extremely happy. The size and shape of the field prevented my making a circle in the air within its limits. To circle, it was necessary to take off, fly across a wide ravine some twenty-five feet deep, with a swamp at the bottom, continue the turn over reasonably smooth land, and, finally, after crossing a small river, return again to the point of departure.

On the afternoon of the next day, I took off with the S-2, having in mind a flight which would bring me back to the point of departure. The little plane climbed easily to about twenty-five feet. I crossed the field, flying a straight line and approaching the boundary, and started to turn towards the ravine. The smoke of burning castor-oil and even drops of it were thrown by the propeller blast on my hands and face. The little plane was smoothly sailing through the air, gradually gaining altitude and giving the most delightful feeling of flying. I crossed the border of the ravine and was then some sixty or eighty feet high over the swamp. Instead of the rush of the ground under the plane which was so familiar during previous runs and low flying, I now saw the ground far below moving slowly, and I had the wonderful feeling of flying, floating in the air. My joy, however, was of short

duration. Being busy with my first turn in the air and with the new sensation, I did not notice soon enough that the swamp below had started to move up towards the plane. Instinctively, I pulled the stick. The ship's descent was slowed for a moment, but then it became much worse, and the next moment the S-2 crashed on the opposite slope of the ravine. I climbed out from the debris of the plane with only scratches and bruises, but the S-2, including the engine, was a complete wreck.

There was not even any question of repairing it. The loss of the plane and engine was a hard blow, and we were further distressed because we could not find out the reasons for the trouble. Before I took off, some of the people present went to the end of the field to get a good view of the plane in flight. They saw the whole event at close range, and their observations were in complete accord with my own impressions. It was certain that the plane was in normal position at all times and the motor worked well until the very moment of the crash.

The exact reason for that disheartening crash was not clearly established and understood until a year later. The S-2, with the 25 h.p. engine and a home-made propeller, had barely enough power to stay in the air, and flew only a few miles above its minimum speed. There was not a single instrument on board. In fact, speed-indicators for aviation were not yet in use. Therefore, I had no way of determining the loss of speed except by feeling and experience, and of that I did not have much because my total time in the air was then not over eight minutes. The S-2 had just about enough power to maintain horizontal flight.

The turn required a little more power, but the chief trouble was created by a sort of air pocket, which existed frequently above the cool swamp in the ravine. Later on, I crossed it many times with more powerful and efficient machines, and while I could often feel the down-pull, I would pay no attention to it. But for the little S-2, it was enough to cause a loss of altitude. By pulling the stick I made matters worse, stalled, as we call it now, and came down abruptly.

During its whole career, the S-2 spent some eight minutes in the air. The longest flight, lasting forty-nine seconds, was the last one. Yet these few minutes in the air represented almost the only reliable source of practical information with respect to design, construction, and piloting that were at my disposal. I learned many important things during these short hops, mostly of a few seconds each. Many fundamental perceptions, such as take-off, action of the controls in the air, and in landing, which only two months previous I had tried to imagine, now became reasonably clear facts which I could understand. But, together with the beginning of actual experience and knowledge, came the realization of the great difficulties of pioneering in aviation. Reflections of that sort, as well as many others, occupied my mind while I took a few days' rest after that significant flight, and "landing."

The S-2 was down and out. For the sake of economy, I removed the bolts, turnbuckles and cables which represented nearly all that could be salvaged. The helicopter was disassembled and placed in permanent storage. The little 15 h.p. motor was sold and the 25 h.p. engine was damaged beyond repair.

The new programme of work was, nevertheless, quickly decided upon, and during the month of July, I made a design, prepared drawings, and soon afterwards started the construction of the next plane. This ship, to be known as the S-3, was in general similar to the previous one, but it was larger, was designed to have a 40 h.p. motor and boasted various improvements which were the result of the experience gained with the S-2. The ailerons were larger and of better design, and the control cables were tighter, since the looser cables on the first two planes had not given the quick response which was so necessary. The wings were more accurately constructed, and were also better covered.

In August I made a short trip abroad, visiting Paris, and obtained a 40 h.p. Anzani motor. About three more months of hard work, and late in November, 1910, the S-3 was completed, transported to the field and assembled.

Early the next month I made the first flight, again crossing the field from one end to the other. The plane was obviously superior to the previous one. The take-off, control, and other characteristics were much improved, and there was a good excess of power.

Winter was early that year and the small river and the few lakes situated around the field were frozen solid. During the second week of December, I made several more flights on the S-3, gradually gaining familiarity and confidence with the controls. All these hops from one end of the field to the other lasted about half a minute. The plane would climb easily to some forty feet and would clearly have gone higher, but I could not push the plane up and land within the

limits of the field. During these few days I made in all twelve "hops," and then decided to try again a real flight, a complete circle in the air landing near the place of departure.

On Monday, December 13th, commencing the thirteenth flight in the S-3, I took off from the usual spot and gradually climbing, left the field at some eighty to one hundred feet altitude. I carefully started a right-hand turn. The plane obeyed the controls and stayed in the air excellently. From time to time I made small movements with the control levers in order to check the responsiveness of the ship. Glancing around, I noticed that the field had already been left behind and that the snow-covered ground was farther below than I had ever seen it before. My joy, however, was again of short duration. At first I suspected, and then saw for certain, that the engine was gradually losing power. Next, I realized that the plane was already unable to hold the altitude and was coming down. My piloting in this emergency was not so bad. Pushing the stick, I prevented the plane from losing more speed and finally made a somewhat rough landing which, however, the plane was strong enough to stand. Unfortunately, it happened to come down on the surface of one of the ponds. The ice was strong enough to hold a man, but, under the impact of the plane, it broke and the S-3, badly damaged by the broken ice, turned over and sank nose down. The pond was about four feet deep in this place, and the trailing edges of the wings and the broken tail stayed above the surface, while the motor lodged about two feet below. Sitting behind the motor, I was completely submerged in the water, but managed to crawl out with-

out much difficulty from the wrecked ship. Pushing aside the floating cakes, I reached the edge of the solid ice, climbed on it, and waited there a few minutes for the arrival of my men. They confirmed my observations, saying that the engine apparently lost revolutions. On that calm winter day they could hear the motor plainly, and were able to recognize the loss of power from the sound. Someone even said that it appeared similar to the noise of the engine when run with retarded spark.

To find the cause of the trouble was very important, and feeling that I could not get any more wet than I already was, I went back to the plane. I could not see the engine, which was about two feet below the water, but by inspecting the rear part I located the distributor and found it shifted all the way to the retarded position. Therefore, the cause of the crash was at least definitely established. I went home while my men got the plane out of the water and brought it back to the hangar. The mechanic informed me later in the evening that the motor was all right, and the plane, although seriously damaged, could be repaired.

The whole flying career of the S-3 lasted a little over a week and consisted of thirteen flights of a total duration of about seven minutes. The last flight was fifty-nine seconds. Whatever I might decide to do next, it was clear that flying would again be interrupted for several months, and plenty of hard work and expense would ensue before the next attempt became possible.

December 13th was followed by a few days of rather gloomy reflections. It was exactly two years before that I had started active work in aviation.

Expenses already represented a heavy tax on the modest fortune of my father, which consisted of the savings of a lifetime as a practising physician, and of my sister, who had organized and was managing a private school for feeble-minded children. None of the money that I had spent was easily earned. But I never heard a word of complaint, and was at that time not even informed of the criticisms and warnings that some family friends considered it their "duty" to give my father about my "obviously hopeless" attempts. Moral and financial support and encouragement from my father and the rest of the family I most certainly had, yet I realized well the full meaning of the extra mortgage on the house which had been discussed in order that my work could continue.

The two years of work did considerable harm to my studies in the Institute. I was already far behind almost every student of my year. The liberal faculty was willing to grant me the maximum extension that was legally possible, but there was a time limit when a certain minimum of examinations had to be passed. While I had learned much during the two years of aviation work, yet these studies were in a different direction from the programme of the Institute. Besides, I had learned by then quite well that success in pioneering work requires one hundred per cent of one's time and energy. Even ninety per cent would not do. So it was necessary to make a choice. I could resume normal studies in the Institute, which practically assured me a diploma and a reasonable career. In that case it would be possible eventually to take up again work in aviation, but the chance of leadership would be lost.

At that time reliable information and aeronautical science were practically non-existent and the pioneer designer and pilot had only his own meagre experience, practical judgment and imagination to supply the necessary data on which to build his machine. When the plane was ready, and no one could tell whether or not it was any good, the designer had to become a pilot and, having no instructor to explain or give advice, he had to seek flying knowledge by studying the birds, by playing with models, and again by relying on imagination. After a crash it was sometimes difficult to know whether the machine was bad or the pilot had made a mistake, or whether it was something else. In order to win against such considerable odds, it was necessary to invest every bit of energy and time. Not eight hours a day, but often sixteen hours of intense and extreme effort were needed, and even so the results were anything but certain.

My own ideas and feelings about aviation had already changed. At the beginning, the work of design and construction was fun, while the flights in my own machine were anticipated as delightful thrills. Now the construction of the planes became serious work. Still more so was the flying. I had learned by theory and practice that a minor deficiency in the plane or a slight error in piloting, or finally one of several unknown causes, the existence of which I had reason to suspect after the event of June 30th, could result in a crash. This was a source of real worry, but not because of any fear of personal danger. I believed in my ability to get safely out of such accidents, but every serious crash would mean an interruption of flying for several months, heavy expenses, and would

reduce the chances of final success. Therefore, the impressions of the flights, particularly of the latest ones, were quite different from my early illusions. All attention during these flights was concentrated in watching the motor, operating the controls while learning to do so, and watching for the landing. The thrill and happy sensations could be experienced after the landing, by memory and by looking at photographs.

Departures from my original ideas of the early period were considerable. I had a feeling that I had started my aviation work not two but some twelve years before. And the same was to a certain degree true with respect to results. Experience, direct information and the training of my intuition, however, had all gained to an extent greater than the short period of two years. By intuition I mean the ability to arrive at a reasonable solution of a problem when data for a solution by ordinary methods is not available. This was the way most of the design problems, not only in aerodynamics, but even in stress, were solved. While, for instance, the structural analysis of a wing would be itself a simple engineering problem, yet to approach it in a normal way one would need to have information about the centre of pressure, distribution of lift between the upper and lower wings, forces of air gusts, and other details. Since all this was not available, it was necessary to rely chiefly on "guess." In this respect, apparently real progress had been made. I remembered the difficulties with which we were confronted at the early period, many of which now appeared easy and simple. I had a feeling that I had begun to learn to develop the ability which is so important for pioneering and inventive work,

namely the ability to distinguish between the valuable and the worthless products of imagination. The first may be considered as intuitive imagination, while the latter may be called day-dreaming and lead to failure and possibly tragedy.

Finally, in order to view the situation from another angle, I tried to picture what would happen if I were really to desert pioneer flying and prepare myself for a career and a more conventional job. Then I realized that this would mean failure and loss, personal and otherwise. For myself, it would mean preferring a comfortable job to a real chance to work, and possibly leadership in a most interesting line of modern engineering which had captured my whole heart and soul. Moreover, quitting now would waste all the confidence and support which I had received from my family. So as a result of these and other thoughts, a decision was reached not to slow down the work but to push it ahead as vigorously as possible, even if it meant sacrificing my diploma at the Polytechnic Institute. Once the decision was made, my doubts and worries disappeared, at least for a while.

During the latter part of December, a programme of future activity was prepared and the work resumed. I wanted to use as many parts of the S-3 as possible, including the engine, and to produce the S-4 plane, introducing certain improvements. Besides that, I decided to build another aeroplane, the S-5, with a heavier, more reliable engine, larger wing area, different control arrangements, and various other changes, which had been suggested by careful study and an analysis of previous planes. The programme called for both planes to be ready for flight early in the spring.

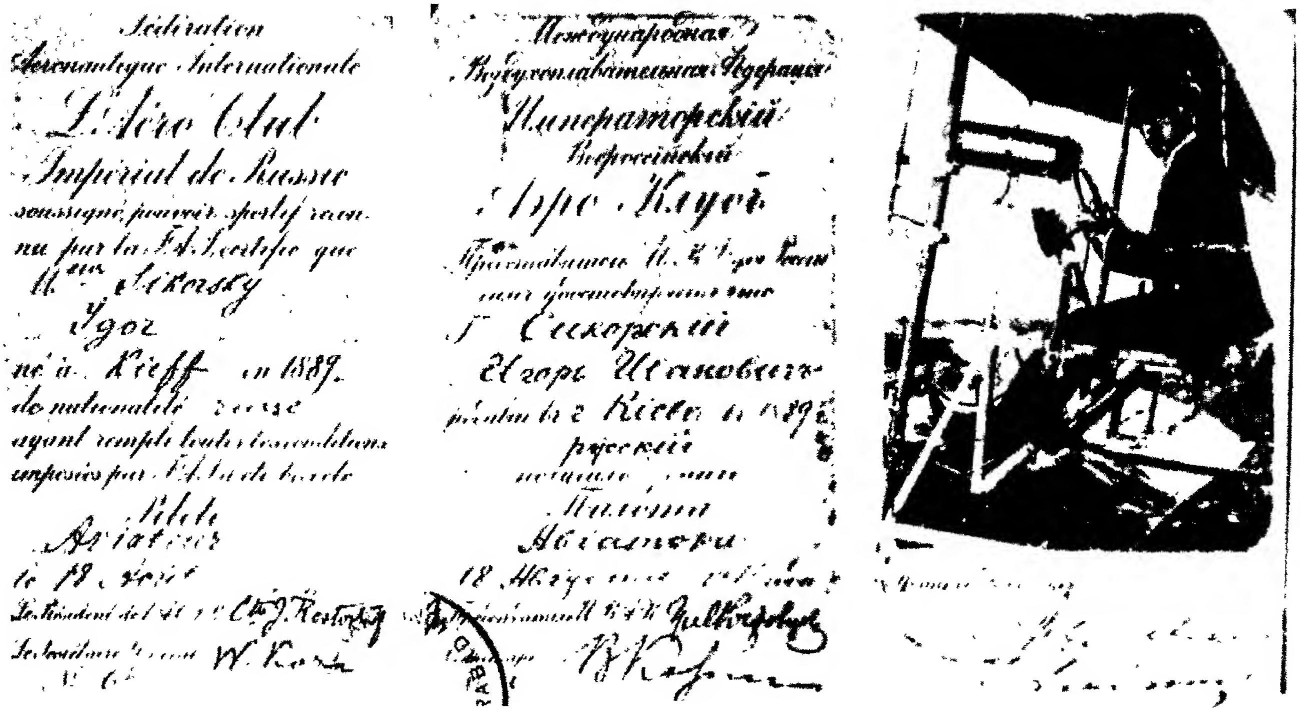
VII

FIRST SUCCESS

THE latter part of the winter and early spring were spent in designing and building the S-5. My interest and enthusiasm for aviation were greater than before, but the character of the activity was now quite different. It became more professional, being done steadily in accordance with a programme.

In April, 1911, both planes were ready for test. The S-5 was larger than any of the previous ships. It had a 50 h.p., water-cooled, "Argus" motor. A wheel control, similar to the conventional arrangement on the majority of modern aircraft, was installed instead of the two sticks used in previous planes for elevator and aileron controls. For rudder control, pedals were used in a conventional way except that the cables were crossed. This meant that pushing the right pedal would produce a turn to the left and vice versa. This appealed to me as being more in accord with the natural feelings of the pilot. I still believe it would be a better method of arranging the directional control of a plane in spite of the fact that the generally accepted way is the opposite. The S-5 was obviously the more promising of the two planes, and in order not to lose time, I decided to concentrate efforts on this machine, leaving the other in reserve.

The S-5 was completed and the power plant thoroughly tested on the ground at the end of April,


Fédération
Aéronautique Internationale
L'Aéro Club
Impérial de Russie
soussigné, pouvoir sportif reconnu par la F.A.I. certifie que
M. Sikorsky
Igor
né à Kieff en 1889
de nationalité russe
ayant rempli toutes les conditions imposées par la F.A.I. a été breveté
Pilote
Aviateur
le 18 ...
Le Président de l'A.C.I.R. ...
Le Secrétaire ... W. ...
No 6...

Международная
Воздухоплавательная Федерация
Императорский
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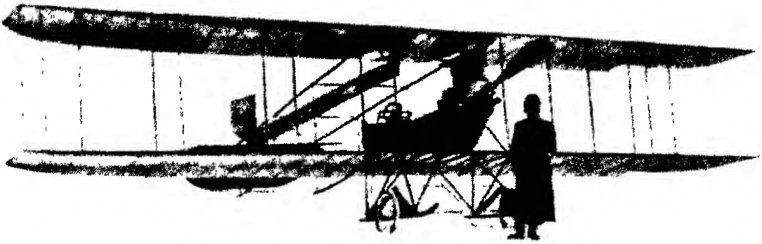
The pilot's licence



The S-6 in December, 1911.

The S-6A in the Spring of 1912

1911. This was again the result of several months of very hard work in addition to the financial burden for the family and some friends who assisted by making personal loans. Almost every part of the plane except the motor had to be built and in several cases designed. The propeller of my own design was made at home; the neighbourhood plumber made a sheet-metal radiator, tanks and other parts; a bicycle repair shop produced wheels using motor-cycle rims, tyres and spokes and assembling them on a pair of wide, crudely made hubs. For shock absorbers I had groups of springs ordinarily used for closing kitchen doors. The fabric on the wings was treated and tightened by a compound devised by my mechanic, which consisted of boiling water, glue and pure alcohol. Other men in the outfit insisted that most of the alcohol was absorbed by the mechanic himself, while glue did the tightening of the fabric. Numerous other difficulties resulted from the almost total absence of aircraft materials and accessories and some ingenuity was often needed in order to eliminate the obstacles. With test flights scheduled to begin soon, there remained in my memory recollections of the two crashes that ended the careers of my two former aeroplanes and the realization that there was no one around to instruct or guide me in the coming most important period. This being the case, it was necessary to use as completely as possible the experience gained by some fifteen minutes spent in the air, and to make a conscientious effort to reduce the hazards by working out and strictly adhering to a sound programme of test flights.

Finally at the end of April tests were started. With a mixed feeling of worry and bright hopes, I took off

for the first time in the S-5 and made a straight line flight of some twenty-five seconds duration. The plane was clearly much better than any of the previous ones. I could feel immediately that it would climb well, or, if levelled with full power, it would gain speed far above the take-off velocity. However, in accordance with the programme I continued day after day the same straight line flying, taking off from one end of the field and landing on the other. After several days of such training with many "hops" every day, I became much more confident. I continued the hops even on windy days when the plane had to be towed back to the end of the runway after every flight. The crowd that came to watch was enthusiastic at the beginning, but became more and more sceptical.

"Hey, what's the use of these little jumps? I'll fly the plane for you."

Several such comments came from the crowd. I could see they thought I was afraid to fly.

"It's not worth while to work three years in order to fly three yards high."

In spite of all this the hops along the runway were continued. Then I started to make small turns deviating slightly from a straight line, and turning back and landing as usual. Thus three weeks of training passed. Finally, I decided it was time to make a real flight.

Early on the morning of May 17th, with no one around except the few persons closely related to the work, the S-5 was wheeled out of the shed and the engine started. A few minutes later I was in the air, realizing the importance of the attempt and yet somehow feeling confident that this time it would not be a failure. The weather was very smooth. All my

attention was concentrated on the controls. Once in a while I moved them slightly to see how they would work. Soon I realized that I was higher than ever before. Everything went along beautifully. My attention was focused on the plane as well as on a small white cabin ahead, because having passed that landmark I had to start turning. After a short time, which seemed very long, I saw the cabin far below on my left. I gradually pressed the pedal until the plane started to turn. Having successfully made my first turn, I became confident that I could make the others and for the first time looked freely around and realized the joy and beauty of flying.

The ground appeared far below. The plane was at an altitude several times higher than the huge pine trees on my right on the border of the field. I realized then that I was much higher than I had intended to go, but I felt happy and sure of the plane. After flying in this new direction for another mile and immensely enjoying every moment of it, I started to make my second turn. I pressed the pedal a little more and this time permitted the machine to take a small list. The turn became better and quicker. I continued it until the desired direction was reached and I could see straight ahead, but far away, the field of my departure and of the expected landing. The S-5 was two or three hundred feet high at that moment. I pushed the control wheel, and the plane began to descend. Pushing from time to time the contact button on the control wheel, I could prevent too much speed and still I could keep both hands on the wheel. Attention was again focused on the last problem, that of landing under somewhat novel conditions. Playing with the engine,

I succeeded in bringing the plane down and finally made a reasonable landing, close to the point of departure. This was a happy day. The two and a half years of hard work had finally resulted in success.

I had been in the air only about four minutes, but this had been a real flight, completed along a course that had been previously decided. While very happy, I felt somewhat tired from previous worry and strain and made no more flights that day. The S-5 was wheeled back to the hangar by the few men that were present with respect and almost admiration. I went home remembering the joy and splendour of flying which I had felt for the first time, realizing that a real step had been made forward in my aviation activities.

The next few weeks confirmed these hopes. The first flight was followed by others which gradually became longer, higher, and better. By the middle of the summer, I was able to stay in the air half an hour at a 1,000-feet altitude. I often enjoyed immensely these flights over the hills and woods in the neighbourhood of Kiev on the wings of the slow open plane of the early days, behind a small motor. This flying could give a delightful sensation which is partly lost in modern heavy, powerful aircraft. On the S-5 I sat entirely in the open just above and behind the lower wing. The view was free in nearly all directions, including straight down. By that time I was used to the controls in the air and the movements became automatic, which permitted me to look around freely and to enjoy the sensation of flight.

In the fall I passed my examination for an F.A.I. pilot's licence which at that time required five figure-eights in the air, landings, and so forth. The Imperial

Aero Club of Russia issued me F.A.I. pilot licence No. 64. In September I was invited to participate in the Army manœuvres near Kiev. This gave me a chance, and a reason, for my first cross-country flight from Kiev to the village Fasova, some thirty-five miles away. During the manœuvres I made a flight of one hour at an altitude of 1,500 feet, and afterwards I had for the first time the honour of being presented to the Emperor Nicholas II.

Later in the fall I earned for the first time a small amount of money by making an exhibition flight at the neighbouring town of Bielaia Tzerkov. While flying there, a minor accident happened which was not without influence in the later development of my activities. The demonstration flight had to be started from a race track which was surrounded by houses and trees, and a railway station. I took off and climbed over the surrounding trees, but when some 150 feet of altitude was reached, my motor stopped. I was just above a group of large trees with no chance to turn back because of insufficient altitude and no room for a normal landing. I quickly picked out a narrow railway yard some 200 feet long surrounded by a stone wall and bordered on one side by a freight train. I glided into this place and purposely made a rough side landing in order to smash the landing gear. The whole manœuvre ended very well. The landing gear was broken, the plane turned over and came to rest fifty feet from the end of the railway yard. That was exactly what I wanted because it was the only way to prevent the plane from running straight into the stone wall immediately after the landing. I climbed out and had plenty of time to inspect the plane in the yard

peacefully because it took some ten or fifteen minutes for my men to reach the ship. I found out quickly that there was no serious damage. The landing gear, the propeller and some parts of the tail were injured, but the ship could be repaired within a week. Looking around, I realized that it would have been much worse if this little yard had not existed because the surrounding area was covered with buildings, trees and railway cars. Sitting beside my damaged plane on a pile of railway ties, I decided that the next important question in aviation was safety in forced landings. The failure of the engine was caused by a mosquito that happened to get into the petrol. It was drawn in the tiny jet of the carburettor which became effectively blocked, thus stopping the engine.

The flights in that year furnished a vast amount of experience and information, as well as encouragement. During the Army manœuvres the S-5 proved faster than the Army squadron that consisted of planes of leading foreign design, which were powered with rotary engines of the same power but of much lighter weight. This confirmed my belief in the importance of reducing the air resistance of parts of a plane. While the first planes were designed chiefly on the basis of "best guess" and various "ideas," by now I felt more and more the necessity of analysis based as much as possible on facts and figures. Very little reliable information was available and for my future work I had to use experimental data obtained from the flights on the S-5 in order to produce the next plane, which was to be a three-seater biplane similar in general to the S-5, but of better design. The plane was to be powered with a 100 h.p. Argus motor. The

speed and lifting capacity were expected to be superior to any other plane then in existence in Russia.

With this ship I had hopes of placing my aviation activities on a self-supporting basis. The construction of the S-6 was started in August, 1911, and was pushed ahead very efficiently during the fall when the flights on the S-5 were curtailed. During the latter part of November the S-6 was completed and the flight tests were started. The results were not very encouraging. The ship was indeed faster than the S-5 and the control characteristics were generally satisfactory, but the take-off run was long, the landing speed and distance of run after landing appeared excessive and finally the climb and lifting capacity did not appear much better than that of the S-5, in spite of twice as much power. After a few flights, I found out that the S-6 needed much more room for take-off and landings and was more difficult in operation, particularly in landing. The flights were temporarily discontinued and during the next few weeks a serious investigation was made of ways and means of improving the new plane.

The trouble with the S-6 had happy consequences. It made urgently necessary better methods of aerodynamic analysis. In order to get information about resistance, I devised and produced a primitive machine for testing the air drag of various parts. The machine consisted mainly of an axle supported on two bearings, with means to rotate the axle by a heavy weight and a string wound near one end. Near the other end of the axle there was a disc about twelve inches in diameter on which it was easy to fix models of struts some three or four feet long or other parts to be tested. The tests consisted in permitting the machine to

rotate, and comparing the velocity after it became uniform with the velocity of rotation of a given body. It was a crude method, but it supplied the necessary information not only comparatively, but even in figures because the weight and diameter of the axle being known, it was easy to find the resistance, while the speed could be established by measuring the r.p.m. with a stop watch and multiplying by the distance travelled in one revolution. The machine was inexpensive and what was more important, it could be produced with no loss of time. Various other investigations were undertaken, and a more accurate and complete aerodynamic study of the S-6 was made. It enabled me to improve the plane. The S-6 was disassembled, brought home, and changes were made in a rush. Before the end of December a plane substantially different, which received the name of the S-6-A, was on the field ready for tests.

The span of the plane was increased by the addition to the upper wing of two sections about five feet long. The open tail was replaced by a wood veneer fuselage which included the seats for the pilot, two passengers, and the engine nacelle. These changes reduced air resistance. The plane was cleaned and streamlined where possible. In spite of cold weather and snow, it was tested. The improvements exceeded expectations and the take-off and landing characteristics were now entirely satisfactory. The climb and lifting capacity appeared excellent. After a few flights the ship performed very well when I took one, and later two passengers on board. During one of these flights, with three men on board, the S-6-A developed a speed of 113 km. per hour (about seventy miles per

hour). This exceeded the world record of speed for a plane with a pilot and two passengers, and was gratifying from every standpoint.

The marked improvement in the plane was not obtained by good luck or blind cut and try method. It was the result of planned effort based on an analysis of the characteristics of the S-6, and on research by methods and equipment that were available. While both were primitive and crude, yet they proved to be basically correct and, therefore, led to new and more ambitious plans. The general idea of a large flying ship with several motors, and comfortable closed cabins, had been an ideal for a long time, but none had been designed. It was in December, 1911, after the successful work of transforming the S-6 into the S-6-A, that I started actual calculations, drawings and even full size lay-outs of a large aeroplane with four motors.

In February, 1912, the S-6-A received the highest award in the Moscow aircraft exhibition. During the following spring I completed negotiations, and entered into an agreement with the Russian Baltic Railroad Car Factory. The contract included the sale of exclusive design rights on the S-6-A and all other designs and inventions in aviation that I had, as well as the ones that would be made during the five years to come. It further gave me the position of designer and chief engineer of the aircraft factory of the company. In addition to a salary and royalties, the contract stipulated my right to build not less than one experimental aeroplane of a new type every year, at the expense of the company. It was understood that I would move to Petrograd within two weeks and would assume my new duties.

This event completed the first period of my avia-

tion activities. Looking backward at that time, I realized to what a considerable extent this success was due to the support and encouragement which I always received from members of my family. I must also mention the fine co-operation and honest, hard work that was always done by the small group of men who worked with me during the three years. Supervision was unnecessary in our small shop in the arbour in my father's garden. Whether I was around or not the work would proceed as efficiently and quickly as was humanly possible. Besides doing actual work, this group as well as a few of my friends, enthusiasts of aviation, participated actively in the solution of current problems and in the overcoming of various and numerous obstacles. Without this loyal and enthusiastic support, the S-6-A could hardly have become a reality. All the six men who formed my "permanent personnel" accepted my invitation to move to Petrograd. Most of them remained there for several years and eventually became foremen.

Easter vacation I spent with my family in Kiev, ready to leave in a few days for my new place of work. It was a great relief to think that the financial burden of my work was finally removed. During this first period of my aviation activities, a large amount of work had been done and two helicopters, two air-driven sleighs and six aeroplanes were constructed and tested. Satisfactory results were obtained from the fifth plane, while the improved S-6 was very successful and made possible the next step in my aviation activity. Looking back, it astonished me that so much had been accomplished in three years. Seldom was any industry advanced as rapidly as aviation.

VIII

MOVING TO PETROGRAD

LATE in the spring of 1912, I arrived in Petrograd with the S-6-A—which was shipped by railway—and accompanied by my six men. A small factory was rented and very soon work was started in this new subsidiary of the Russian Baltic Company. By the middle of the summer we had about thirty men working. I spent most of my time at the factory. Evenings, when the weather was good, were usually spent at the airport, flying or watching other planes. The best time for personal work was late at night. Quite often I would take a few small cups of black coffee and would then start my work at home at 10 or 11 p.m. and continue up to 4 a.m. I found this to be the best time for creative work.

It was during these summer nights that the preliminary project of a large plane with four motors was completed. It was a most interesting pioneering feat, not just another aeroplane. In many respects it was entirely different from planes in existence, and several characteristics, such as size, weight, closed cabin for the pilot, location of power units far outside the centre line, were strongly opposed by many leading aviation authorities of that time. It was often stated that about one ton of weight was the largest practical size for an

aeroplane and various arguments were brought up to prove this opinion.

A small training plane, the S-8, with a rotary motor of 50 h.p. was completed early in the summer, while two others were under construction. One of them, the S-6-B, was a two-seater, in general similar to the S-6-A, but refined and improved in details. The other, the S-7, was a two-seater monoplane. The two ships were entered in the military competition that was planned to take place in Petrograd during the months of August and September. Both ships were completed in July. I flew from time to time in the S-6-A and the S-8, while from July on I started to use, chiefly, the S-6-B in order to get better acquainted with the plane that I expected to pilot myself during the coming air meet.

The S-7 monoplane was to be flown by the pilot of the company, Mr. George Jankovsky. The rules of the competition required that all planes must have been constructed in Russia. It was permitted, however, that planes be of foreign design. Of the eleven machines that were expected to participate the most serious competitors were several planes built on a license basis from leading European designs of that time. Rumours were circulated that the two best machines of this group were actually original planes, imported from abroad, and then assembled and repainted in Russia. I do not think that this was true. There was no doubt in my mind that the ships were built in Russia, but the work was very well done and they performed fully as well as the original ones.

With leading pilots behind the controls of these planes, keen competition could be expected. In accordance with regulations, the award of prizes had to be

made in the order of the number of points earned by each competing aeroplane, providing the ship qualified, which meant that it had to pass certain obligatory tests. The points were based on high speed, minimum speed, rate of climb, take-off run, excess useful load above the normal load, which was established for each plane in accordance with the power of the engine and a few other items. The tests also required the demonstration of an ability to take-off and land within a given short distance, a climb to 1,500 metres (4,900 feet) in less than fifteen minutes, and finally the take-off and landing from a freshly ploughed field. All these flights were to be made with full load. In general, the requirements, as well as the competition, were quite serious. With interest, as well as with a certain amount of worry, I was waiting for the beginning. In the past I had heard compliments and encouragement from my relatives and friends, but now it was the stop-watch and altimeter which would pronounce judgment on the relative value of my planes compared to the other ones.

The first week of the Army competition fully confirmed my expectations that the affair I had let myself into was a very serious one. While the basic performance of my ships was higher, yet the other outstanding ships, with their light rotary engines, showed better take-off and landing powers. The race for points would be a close one.

By the end of August, I made several officially recorded flights, and expected soon to complete all of them, when unforeseen trouble changed the whole situation. After one of my hops, while approaching the field for a landing, I saw a group of men running towards the spot where I expected to land. I made a

sharp turn and a rough side landing, wiping out the landing gear and propeller and damaging several other parts of the plane. My mechanic and I received numerous bruises, but needed no assistance to get out of the ship. Nevertheless, my mechanic was sent to a hospital, while I went away to Finland for a few days of rest, leaving instructions to have the plane repaired as quickly as possible.

During my absence my men accomplished a miracle and by working day and night repaired the badly damaged plane in four days. This proved to be a disappointment to some of my competitors who expected that I was down and out. When I returned I found that the plane was again ready to fly. However, new difficulties appeared ahead. In view of the seriousness of the repairs and the possibility that some of the characteristics of the plane might have been changed, the management of the meet decided that I must repeat every test flight. There was less than one month left and the weather, often bad in Petrograd in September, made it difficult to pick out good days to show the really high performance of the ship. Still worse was the situation with respect to the ploughed field. My competitors, with their lighter machines, had made the test during the nice dry days of August. But the long rains of September transformed it into a muddy swamp. As time went on, the clear days were few, the weather was cold with much rain and the ploughed field remained in hopelessly bad shape for my heavy, fast plane.

The military airport on which the competition took place was situated some ten miles from my home. In order not to miss any flying weather, I decided to move to the airport. A small stove and a couple of windows

were put in a box in which we used to ship disassembled aeroplanes, and we obtained a home with Captain Jankovsky near our planes during the remaining time of the competition.

The weather was mostly bad. Taking advantage of every possible chance, usually at daybreak, I succeeded by the middle of September in making most of the required flights. My plane was leading with respect to speed, climb, and useful load. However, it was behind in take-off and landing run. With the points now gained, the chances of winning one of the prizes were good; even the first prize appeared possible provided I could take off from the ploughed field. If not, the plane would not even have qualified for the competition and all our efforts would have been worthless. The fact that the field was swampy could not be used as an alibi. I had had as many chances to use it during the good August weather as my competitors. The accident was just my bad luck.

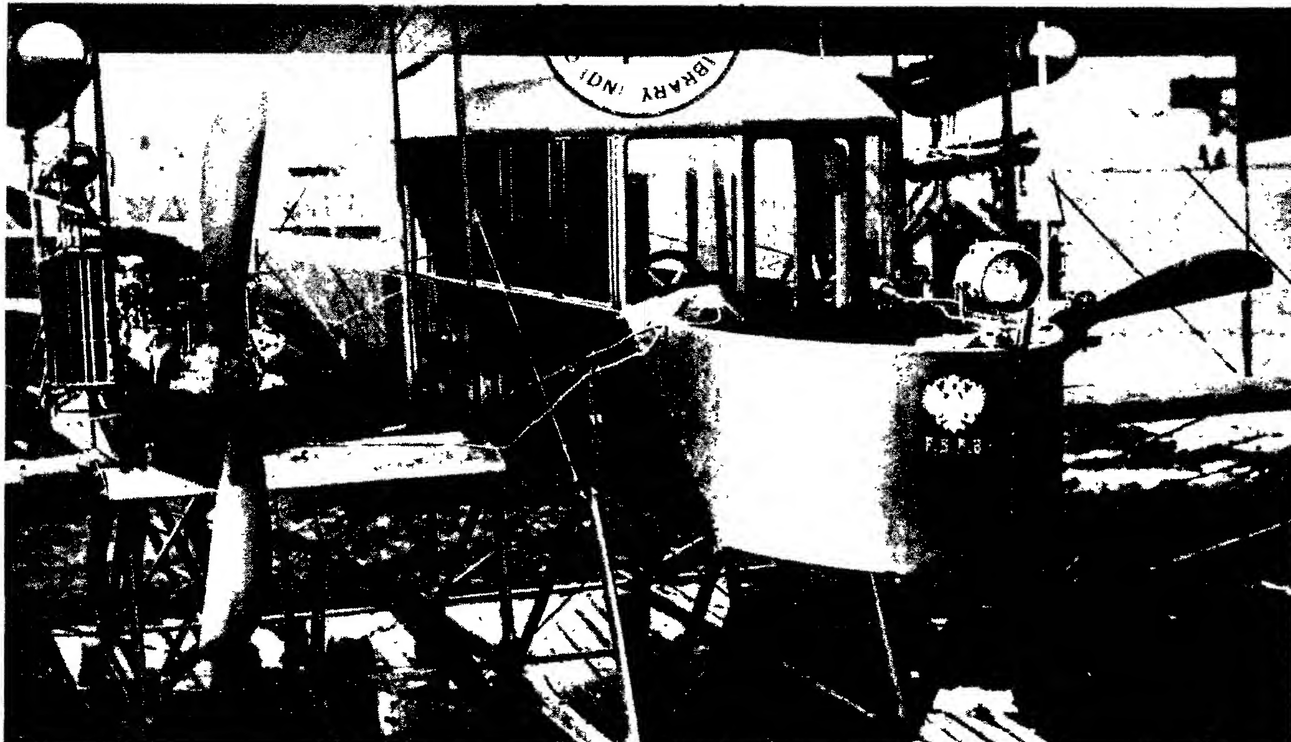
IX

THE NIGHT OF SEPTEMBER 17, 1912

AS the days passed, I watched the ploughed field which, to my growing disappointment, remained in a hopeless state. In the meantime I continued to fly, and on September 17th made the required one-and-a-half-hour endurance flight, combining it with a climb to 1,500 metres (4,900 feet), which I decided to do late in the afternoon upon learning that bad weather was coming and that for several days flying would be impossible.

I started late and completed the flight in darkness, coming down near a fire which my men had started at the usual landing-place. Tired and somewhat frozen, but well satisfied with my first night flight which had been accomplished in rough weather, I returned to our hangar and there received a message that included an invitation to dinner by the Chairman of the Board of the Russian Baltic Company. I just had time to change my flying-suit and start for this dinner-party, little realizing at that moment that this evening would have fundamental consequences for my whole life. In order to make clear the events of this evening, let me give some information about the company with which I was connected.

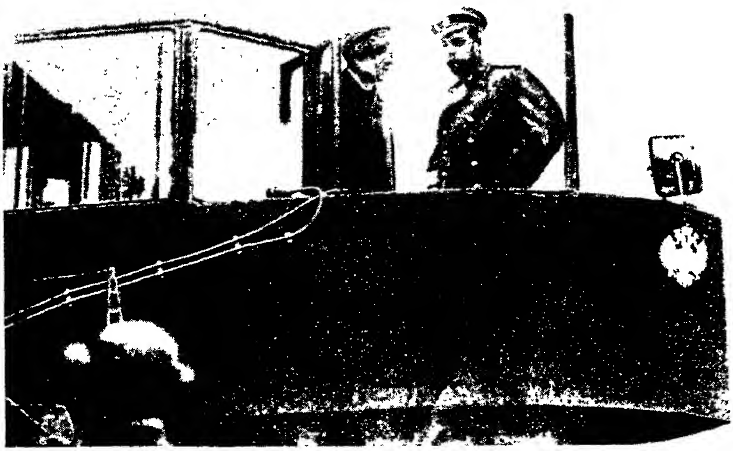
The complete name of the organization was the "Society of Russian Baltic Railroad Car Factories." At



The " Grand " in May, 1913

The Emperor Nicholas II inspecting the “ Grand ”

The Grand Duke Nicolas, eventually Commander-in-Chief of the Russian Army in the Great War, at the extreme left



The Emperor Nicholas II and the author on the balcony of the “ Grand ”

that time it was one of the leading industrial organizations of the country. In addition to the railroad car factory, which produced about five hundred cars per month, it had a division for producing agricultural machinery, an automobile factory which turned out excellent cars, several other departments and also a small aviation division, of which I was at that time manager and designer. The remarkable progress and expansion of the company, and the decision to start automobile and aeroplane construction were all the result of the activities of one outstanding man who occupied the position of Chairman of the Board of the company, and who actually had complete authority over the policies and management. The person to whom I am referring was Mr. Shidlovsky, himself a large stockholder in the company. A man of outstanding intelligence, as well as moral character, he created respect and admiration. He had the unlimited confidence of a substantial group of other investors. His word was law to anyone within the huge group of organizations; and, outside, his word was a more reliable guarantee of any transaction than a contract drawn up by the best lawyers. This was equally true whether it concerned another powerful corporation or a humble and defenceless individual. At a later date when I had the good fortune to become much better acquainted with him, I listened with great interest to the story of his earlier life.

Born in an aristocratic family, and graduated from the same Naval Academy in which I studied some thirty-five years later, Mr. Shidlovsky started his career as a naval officer and lieutenant commander, and made a round-the-world cruise on a clipper ship of the

Russian Navy. Eventually he resigned and accepted a position in the Treasury Department. His ability and outstanding personality enabled him to progress rapidly in this government service, and within a few years he reached one of the highest positions and was considered a candidate for the post of Secretary of the Treasury. At that time he invested a major part of his wife's fortune in stock of the Russian Baltic Car Works. The organization was in rather bad shape and within a short time the stock fell considerably below the figure at which it had been purchased.

Feeling that he himself was responsible for the loss, Mr. Shidlovsky, who at that time did not possess a large personal fortune, decided to resign from the government service and devote his energy and time to the rehabilitation of the Russian Baltic Works. He inspired confidence in the other stockholders and was elected Chairman of the Board. While he had never before been connected with industrial enterprises, he learned quickly and started a reorganization. Obsolete buildings and equipment were replaced, necessary changes in personnel and methods of operation were introduced and within a few years the organization was placed on a sound basis, working efficiently and successfully. The stock again sold high. By that time Mr. Shidlovsky was planning further expansion. It was his ambition to design and produce automobiles in Russia and later on aeroplanes. He succeeded in both of them, and it was exceptionally good luck that I met him at the proper moment, offered my services and secured the position of aircraft designer of the company.

It was around eight o'clock on the cold and windy evening of September 17th that I arrived at the home

of Mr. Shidlovsky, which was located in a good residential section of Petrograd. To my satisfaction, there were only members of the family at home and no other guests. After dinner, Mr. Shidlovsky and I went to his study where I made a brief report of the situation with respect to the air meet. The subject proved to be of little interest to my host and so I made my story short. There was silence while we drank black coffee which we both liked and, feeling that my chief was not inclined to discuss business, I changed the subject and briefly outlined a few of my general ideas on the subject of the future of aviation. I mentioned that the aeroplane of the future must be much larger in size, weight and power, must be designed along different lines, and would prove to be much more successful and more reliable than small, single-engined planes. When I stopped my host suggested that I continue my story. I went on describing in more detail the characteristics of the air giants of the future; the necessity of several motors, one independent of the other, as the only protection from hazards of forced landing in case of engine failure which was so frequent at that time; the importance of a crew of several men who would assist and relieve each other and fulfil the duties of the pilot at the control wheel, the navigator, the mechanic and others. To enable them to perform their duties properly, a large, comfortable closed cabin was necessary, particularly in the severe climate of Russia. The characteristics of such a flying ship would be such as to allow the crew to reach the motors in flight for inspection and minor repairs.

During this discussion I stopped once in a while, but each time Mr. Shidlovsky would urge me to con-

tinue with more details. Encouraged, I went more to the point and informed him that for more than one year I had been working on the actual plans of a plane with four motors, a closed cabin and various other new characteristics. I pointed out that no such ship had ever been successfully produced and that the idea was condemned as impossible by many, if not by most, of the authorities on aviation. It was my firm conviction, however, that such an aeroplane could be produced and that if built and demonstrated, it would open the road to most interesting and encouraging possibilities. The conversation proved to be a long one as I explained further details and made sketches of the proposed flying ship.

It was close to midnight and time to go. Thanking Mr. Shidlovsky for his kind attention, I said that the military air competition would soon be over and in the event that we won, I would suggest that the prize money be invested in the construction of such a large flying ship. His brief reply was: "Start the construction immediately." Realizing the great importance of what had happened, I drove home along the beautiful and dignified Kamenoostrovsky Prospect of Petrograd. At that time I lived in an old, picturesque house built during the time of Catherine the Great situated near our new factory. Before going home, I stopped at the factory gate and ordered the night watchman to telephone or to find some of my assistant engineers and foremen and ask them to come to my home immediately. It was past one o'clock when the men, sleepy and amazed, arrived one after another in my home.

We all went into my living-room and I served each

man with a small glass of wine to make the matter more solemn and then informed them about the important news. Needless to say it was received with the greatest enthusiasm. Congratulating each other and shaking hands, we emptied our glasses to the success of a new and great enterprise. All this lasted only a couple of minutes, while the next three hours we had a serious business conference. The work ahead was not easy, and again called for pioneering efforts. Most of the night was spent in a discussion as to the best and easiest type of construction, general methods, materials that could be purchased immediately, and so forth. It was an extremely efficient conference, such as can be made only on the basis of friendly loyalty and enthusiasm. We finished about four o'clock. The work of preparing drawings, preliminary lists of materials, sketches for parts to be tested and some of the other items was actually started the next day. Within a very short time the construction of the first successful four-engined aeroplane was under way.

During the next two or three days the weather was bad. It was useless to return to my temporary home in the aeroplane box on the flying field. I spent this time at the factory, having conferences and making arrangements in connection with the large plane. A quick revision of my former drawings was made in order to adjust the project to the materials that could be readily obtained in Petrograd. There was little aircraft material available at that time so we had to use other stocks that could be purchased in the city from automobile and bicycle repair shops, marine hardware and lumber yards. The design work had to be followed by direct contact with the purchasing de-

partment in order to avoid considerable and indefinite delays.

About the third week in September, I went again to the flying field. The rain had stopped, but the field was wet and the ploughed section worse than ever. It was a cold, cloudy day; the airport was nearly deserted. I decided to stay on the field and continue to watch the weather for some sort of a break. During the next few days, I completed all the remaining tests, except one. The rest of the competitors had either completed all of the required flights, or at least all that they were able to accomplish. There were three prizes available, the first one, 30,000 roubles; the second, 15,000; and the third, 10,000 roubles.

My plane had the highest number of points with an ample margin. But the two closest competitors had completed every flight that was required, and I still had the ploughed field to make and if this could not be done my plane would not be qualified to get even the last prize. All efforts would then not only be worthless but even harmful.

The 25th of September went by with only four days left. The following day was again cloudy. During the night I could hear the rain hitting the top of my box house. Next day I walked to the ploughed section, nearly lost my high rubber shoes and, with gloomy reflections, went back. Some friends advised me to take a chance and make an attempt. I did not want to do it; I knew the plane could not take off. It would get stuck in the mud and probably would nose over. On the 28th of September, with two days left, the situation remained the same. There was, however, a complete change in the weather. It

was a beautiful day with the sun shining and not the slightest wind; comfortable in the sun but quite cool in the shadows. After sunset, I went to Petrograd to a restaurant where there was good music, for a little rest and recreation.

I returned to the field about nine in the evening. The night was dark, beautiful and very clear. I took a walk over the field, enjoying the sight of the stars that were out in unusually large numbers. It was very cold; I could soon feel it on my ears and fingers. This ordinarily unpleasant feeling made me happy and hopeful. I went early to my box, had a good rest and was up again at four o'clock. Quickly I walked the half-mile across the field and reached the ploughed section. My hopes were not in vain. The ground was frozen as I walked across it. The surface cracked slightly under my feet, but it was reasonably hard. Hurrying back I realized that my difficulties were by no means over. The field was indeed reasonably hard, but it was very rough and there was not the slightest wind. Nevertheless the conditions justified an attempt.

Returning to the hangar, I ordered the plane out, called the two officers on duty to act as official witnesses and as soon as everything was ready, had the ship moved towards the ploughed section. It took some time to make an official check of the plane for the amount of fuel and useful load, and it was shortly before sunrise that all was ready. The official witnesses followed the plane while I waited for a few moments, wishing to go out alone. My attention was attracted by a fire on the field not far from the ploughed section and the figure of a man warming

himself near by. I went closer and recognized my most important competitor, one of the finest pilots of that time, Mr. Gaber-Vlinsky, and shook his hand.

"What are you doing here?" I asked. "You have completed all your flight tests."

He replied with a friendly smile:

"You are trying to get 30,000 roubles out of my pocket and you don't know why I'm here."

I smiled back.

"Unfortunately I haven't won the 30,000 roubles yet."

There was still no wind at all; this was too bad, but at least it permitted a run in any desired direction. I did plenty of walking around and across the ploughed section and was well aware that the whole field was equally bad and rough. Therefore, I had the plane placed in one corner of the rectangular section in order to take off along a diagonal which would give the maximum distance for the run.

I climbed into the cockpit and ordered the engine cranked, while the official witnesses walked towards the other end of the section to watch the take-off. With small blocks of wood under the wheels and the rest of the men holding the tail, I warmed up the engine for several minutes, gradually moving the throttle until I got the full power. I then signalled with my hand to release the plane. The ship started to move over the rough ground. At first it was difficult to gain speed; a couple of times the wheels broke through the frozen surface of the field, each time slowing down the ship. Still the motion gradually increased. Towards the middle of the section the plane ran reasonably fast, and I could move the control wheel slightly forward

permitting the tail to rise. By that time I was not far from the end. The plane continued to accelerate, and began to make large bounces over the rough surface. I raised the tail a little more, watching the quickly approaching boundary of the ploughed section with the two observers on one side. When I was some fifty feet from the end, I pulled the control wheel nearly all the way back. I could feel the tail skid touching the ground. The plane took off heavily, rose to some ten feet, then started to settle down. It did not reach the ground, however, and having gained a little more speed, it was able to remain in the air and a few seconds later it was flying normally and gaining altitude. I made a circle, approached the ploughed field again at low altitude and slow speed, and easily made a full stall landing.

The next day, September 30th, the competition was closed and it was announced that the S-6-B was awarded the first prize.

The prize money, which was divided between the Russian Baltic Company and myself, gave me an opportunity to return a substantial part of the money to my family and to pay all debts. During the following two years the whole amount that had been given to me by my father and sister for my early aviation work was repaid. The winning of the competition had resulted in an order for a few S-6-B aeroplanes.

More important, however, was the progress of work on the large plane, which in November, 1912, was already well under way. It was most absorbing to watch the construction of the huge wings, particularly of the fuselage with the large, roomy cabin in the forward part. Now ideas and sketches were materializ-

ing into a flying ship which was radically different from the tiny, light planes of that time. The opinion outside the factory was mostly sceptical. During my night work, besides the current problems, I often spent a certain amount of time studying criticisms. Some could be disposed of easily; others sometimes necessitated serious thought. For example, I once heard the following opinion expressed: "The ability of a wing to produce lift is the result of creating a downward motion of particles of air; therefore, the increase of the chord of a wing after a certain size was reached would give little or no increase in lift, because all the particles of air already received the impulse from the forward parts of the wing." This conclusion would appear correct if we were to consider the air as consisting of a series of small, hard balls that are brought into motion by a passing body. We did not know then that most of the lift of an aeroplane is caused by the vacuum on the top of the wing. In some cases, the plane with the same span and a narrower wing would fly and climb better than a plane with a wider chord.

My attention also was called to the fact that nature could only make flying creatures of a certain weight which happens to be several hundred times less than the weight of animals that live on the ground, not to mention those that live in the ocean, and that when nature produced a heavier bird (the ostrich) it simply could not take off. According to the opinion of this friendly and reasonably well informed person, that was exactly what would happen to my big plane. It would run on its wheels, but would not leave the ground. Other critics mentioned stability and control as being

impossible, and illustrated their ideas by saying that a motor-cycle was all right in its size and weight, but it would be wrong to build a large bus on two wheels and expect to have success with it. This was mentioned in connection with the fact that planes of that time were generally unstable, and the pilot had to maintain the proper balance in a way somewhat similar to a motor-cycle.

As a rule I avoided arguments on these subjects. I usually replied in a vague and general way, expressing my confidence in the final success of the large plane. At the same time I often tried to encourage expressions of opinions and later, when I was all alone during my night work, I studied and analysed as completely as I could the criticisms and doubts.

The fine, loyal and enthusiastic engineering group who were working on this design had many novel problems to solve. For instance, there were no aeroplane wheels suitable for the big ship. A special landing gear had to be designed in which sixteen aeroplane wheels were used. It was a complicated arrangement, but it proved satisfactory.

Early in 1913 the fuselage and wings were well under way and produced a substantial impression. The factory personnel started to call the new plane by a short but suitable name, "The Grand"—in the French sense, meaning "large." Almost every evening, when all was quiet and only a few men were around, I returned to the factory to look over the ship. While these were times of hard work and we were often busy fourteen hours a day, yet it was all extremely interesting. From thought and ideas to sketches, preliminary calculations, then to actual analysis and blueprints, and

now to the huge impressive parts of the first four-engined flying ship!

During one of these evenings, a group of men were moving round some of the completed parts of the "Grand." While I watched some twenty men lifting with difficulty the fuselage of the ship, I thought of the predictions of one of my visitors who said that the plane would not leave the ground. When I returned home that night I arranged to have plenty of black coffee and started again to go over my calculations. They were simple and appeared correct, provided of course that my assumptions were right. On this subject there were all kinds of opinions, and many of my critics considered that facts already known would not justify my conclusions with respect to a plane of such size. They pointed to the fact that no successful helicopter could be produced in spite of numerous attempts, while model helicopters could fly very well. This, they said, proved that data based on results with a small plane may not be correct when applied to a much heavier and larger machine. Other similar cases were mentioned and the conclusions were mostly not encouraging. I still had confidence in the methods of calculation that were developed when the S-6 was transformed into the S-6-A. In accordance with these, the large plane would perform all right in spite of the fact that the structural weight was expected to be substantially greater than the preliminary estimates.

In February, 1913, the central part of the plane was assembled in the factory. There were numerous problems to be solved in connection with flying controls, engine installation, and landing gear assembly. Still longer working hours became necessary for the engin-

eering group, but none of the men complained. The numerous obstacles created by the novelty of the work, and the absence of necessary information and materials in several cases, were gradually eliminated by hard and efficient effort, supported by enthusiasm. In April the parts of the "Grand" were transported to the military field for general assembly. Soon afterwards we had the satisfaction and thrill of seeing the "Grand" fully assembled for the first time.

An experienced engineer could have recognized in the large plane several features which pointed to the experimental character of the "Grand." There were a considerable number of wires and cables, and there were a series of skis to support the plane in case the landing gear failed. The plane had a very long fuselage and an extremely powerful directional control arrangement which consisted of four rudders. This was to counteract the dangerous loss of control which was predicted as inevitable in case of the failure of any one engine. For similar reasons several other ideas were incorporated in the design in order to reduce the chances of mishap, including the relatively narrow chord and large span, the very long fuselage and the location of engines in two tandem groups to keep them closer to the centre line.

The "Grand" weighed gross about 9,000 pounds. It had a span of ninety-two feet and was powered by four 100 h.p., four-cylinder, water-cooled Argus motors. Besides the size and general arrangement, substantially novel ideas were incorporated in the pilot's and passenger cabins. The front part was occupied by a large balcony; next came the closed pilot's cabin with two seats, double control and all flying instruments. A door

in front permitted stepping out on the balcony, while the rear door would open into the main passenger cabin. The latter was luxuriously decorated, had four seats, a small sofa and a table. There was full standing room everywhere. A continuous row of large windows gave the cabin excellent visibility. In the rear was a washroom and a cabinet for clothing. Imagination had obviously entered into this fuselage design. It was like something out of Jules Verne though not so impractical.

The completed plane attracted considerable interest and as the time of the test flight approached, there was usually a large crowd watching the "Grand." It took a few more days to test the engines and adjust the controls and mechanisms. To do this it was necessary to get the plane out of the hangar, which in turn increased the crowd. People on the field were betting whether the plane would rise; if so, whether it would crash during the landing, and there was much excitement as the zero hour approached.

X

THE FIRST LARGE AEROPLANE WITH SEVERAL ENGINES RISES SUCCESSFULLY FROM THE GROUND

DURING the second week of May, the plane was completed except for minor details and adjustments of power plant. During these days, I spent much time in the pilot's cabin thinking over the programme, trying to imagine the test flight and to foresee the possible troubles. I went carefully over my past good and bad experiences in test-flying new planes. I also tried to make a final study and analysis of difficulties that were predicted by others. The main points of these were as follows:

1. The plane was too big and heavy and would not rise from the ground.

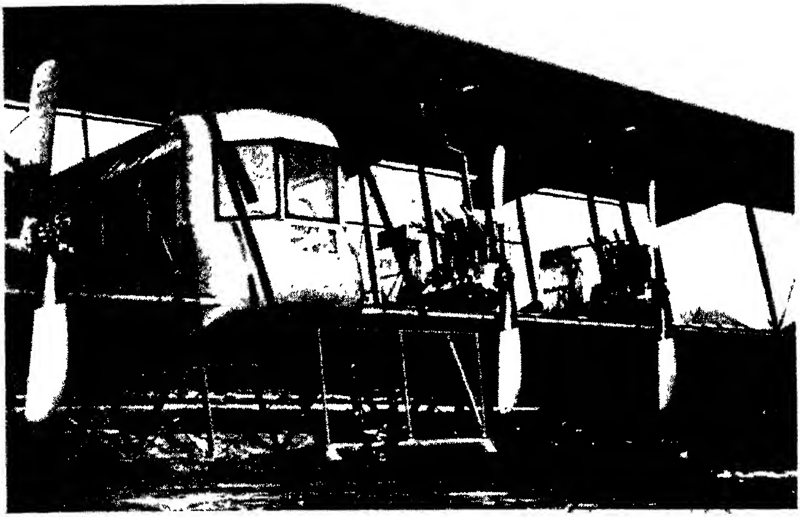
2. The multiple power plant would be a source of serious danger, because if one motor were to stop the balance and control would be so badly disturbed that the plane would crash. This opinion was illustrated by references to a well-known aeroplane disaster of the early period which had happened when a chain broke, cutting out one of the two propellers.

3. Furthermore, an opinion was expressed that the plane was too large to permit proper control in the air, particularly during landing.

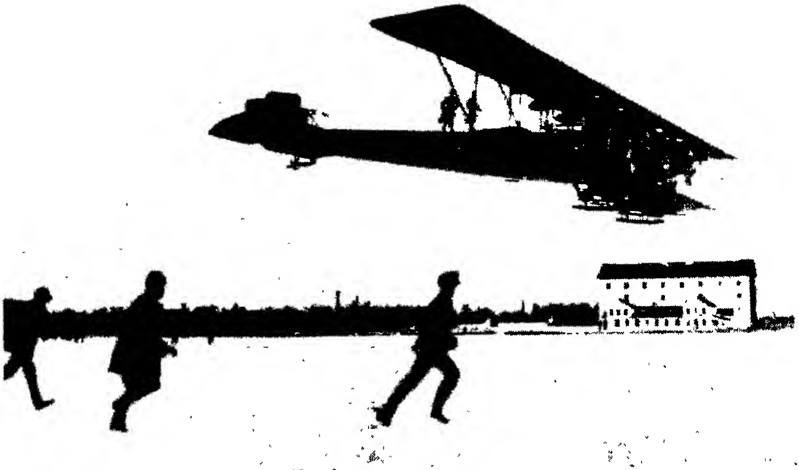
4. Finally, it was argued that an aeroplane cannot be piloted from a closed cabin because the man at the control must feel the air stream in order to realize fully and quickly any change from normal flying position.

In spite of these predictions I was hopeful, and in general confident, but I realized just the same that a minor mistake in control or adjustment might result in disaster. I was chiefly concerned about the possible difficulties of landing. The trouble was the lack of experience with the landing control characteristics of the plane, which could not be known before the first landing. Besides, it was to be expected that the large plane would be tail or wing heavy, or would at first show some other imperfections. This, together with my unfamiliarity with the plane, could result in my making incorrect manœuvres which in turn might cause a crash that would discredit the idea of the large plane. Therefore, an extremely careful and conscientious approach to the first flight was essential.

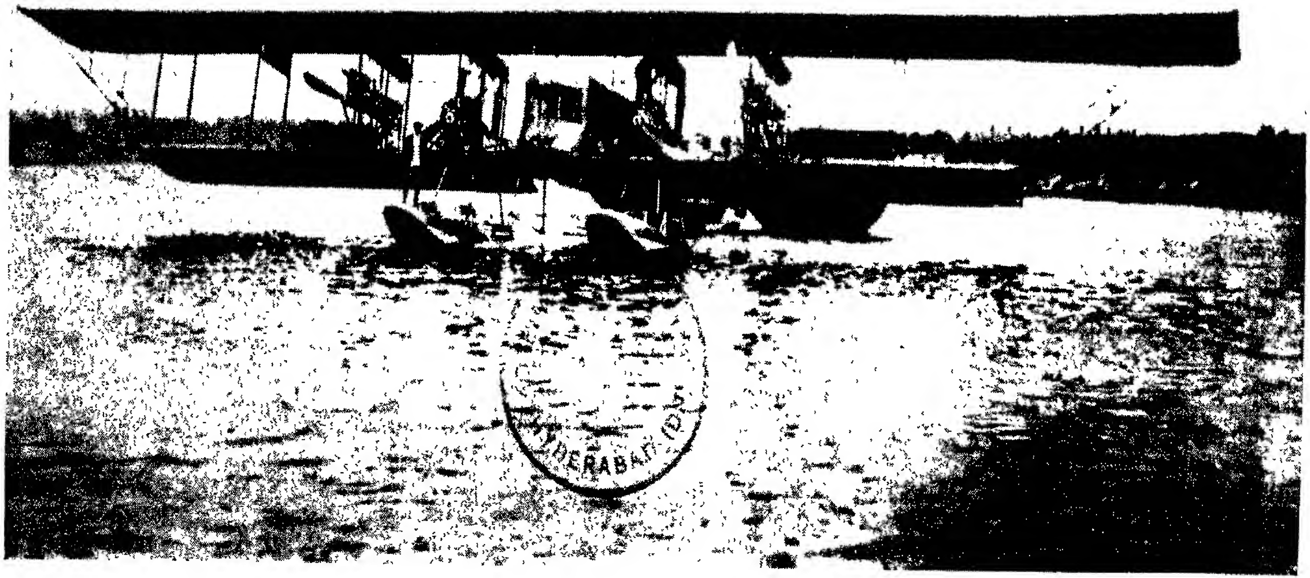
The enclosed cabin was not very disturbing to me. Of course, it was entirely novel at that time, but I relied on my instruments and on my engineering knowledge, rather than on any "bird sense," which in that epoch was often considered essential. There were not many instruments, but I had what was really needed. There were four tachometers for the engines, two altimeters, a U-glass tube with alcohol connected to a sort of pressure receiver to indicate the flying speed, a ball in a curved glass tube to work as bank indicator and a long streamline tube mounted some three feet ahead of the window with divisions to indicate the incidence. The three latter instruments were "home made," designed for the "Grand." They were particularly necessary



The first " Ilia Mourometz



The " Ilia Mourometz " coming to a landing with two of its passengers standing on the upper platform, February, 1914



“ Ilia Mourometz ” on floats in July, 1914

because of the enclosed cabin. On the majority of aeroplanes of that time, the pilot would feel on his face the intensity and direction of the air stream. The first would inform him about the flying speed, while the second would warn him if he were side-slipping. With some flying experience, the impressions would be received and understood automatically and contribute to what was then known as " bird sense."

The great conveniences and comfort of the enclosed cabin would, however, eliminate this source of impressions. Therefore, besides acquiring and installing some instruments, it was necessary to design and make others that were not available, and to learn by imagination how to translate their indications into an understanding of the flying position of the aircraft.

During my " imaginary flights," I studied carefully the position of all these instruments, as well as of the auxiliary control handles, to avoid having to look for them in actual flight.

The test flight programme was finally planned as follows. After the take-off, the general control characteristics were to be tried out and a climb made to some 600 or 800 feet altitude. While at that altitude, I would try to make the movements necessary for landing and see how the plane would respond. Next I would fly away two or three miles down-wind, turn and gradually coming down would prepare for a landing. The actual landing, however, I decided not to make in the usual way but rather as a complete power stall. In this case the position of the plane with high incidence and nose pointing upward must be secured not at the very last moment close to the ground but at reasonably high altitude of, say 100 feet or more. Keeping the plane

in this position the pilot reduces the power until the machine slowly loses altitude. As he approaches the ground the pilot gives a little more power at the proper moment. This reduces the rate of descent and permits a smooth landing. While the large ship would, of course, respond much more slowly to the controls (it was not known at that time how much), yet the four engines would act exactly like one. Therefore, the power stall landing, in which the plane was kept in the same position and the control was maintained by playing with the engines, would be the same in the case of a large, as well as a small, plane.

Finally, late in the afternoon of May 13, 1913, the "Grand" was ready to fly. The Army airport was occupied by some groups that were flying, and we were asked not to make test flights during this day. Around nine o'clock in the evening, I made arrangements for the next day, expecting to leave early. I was tired and had no intention of doing much that evening. I remained on the field, however, to watch for a while the last Army ship land and taxi to its hangar on the opposite side. When I was ready to go, I was approached by Mr. Shidlovsky, who told me that the field was now free. He further mentioned that unless I was worried or indisposed to fly on the 13th, he saw no reason why the big plane could not be tested that evening. To confess the truth, I was not anxious to fly the ship then, but I could not say so, and therefore I ordered the big plane out of the hangar. It was about ten o'clock when the "Grand" was pushed towards the beginning of the runway. In Petrograd at that time of the year there are what are called "white nights," which means that it is never entirely dark, and for

another hour or so light would be plentiful.

While no one had been informed of the possible test, yet a large crowd of people, mostly workmen and residents of the neighbourhood, was still waiting along the border line of the airport. I quickly looked around the machine, checked the amount of petrol, then climbed into the cabin and ordered the engines cranked. I could soon hear their noise, see the blue flames of the exhausts, and feel the slight trembling of the machine ready to go. All my doubts disappeared. While warming up the engines, I looked around once more. As previously arranged, my co-pilot on this flight, Captain Alechnovich, was in the main cabin ready to move to the front or rear if the plane happened to be tail or nose heavy. My flight mechanic was at the front balcony ready to give the sign to release the ship to the men who were holding it by the wings. The runway was clear. I gradually opened the throttles. With the four engines wide open, I waited for a couple of minutes to be sure they were all right and then I gave the sign to my mechanic. He in turn signalled to the men and the next moment the "Grand" started to move.

The plane gradually gained speed along the soft, wet runway. A few seconds later I could feel that the tail went up and the ship continued to gain speed. Inside the pilot's cabin, high above the ground and protected from the air stream, the impression was that the motion was very slow. However, the elevator, and a few seconds later, the ailerons became active, indicating that we were approaching flying speed. I moved the control wheel slowly and slightly backward. The next moment the shocks of the wheels

running along the ground disappeared and the earth gradually started to drop away from the plane. I made a few small and gentle motions with the controls, feeling out the ship. It responded. I continued to climb in a straight line, glancing from time to time at the instruments and repeating those small movements of the controls which are familiar to a test pilot. While almost invisible, they are sufficient to prove that the controls are active and in order. The plane flew extremely smoothly at about sixty miles an hour. It was strange to pilot a ship and not feel a stream of air on the face. Ahead on the front bridge stood the mechanic. Once in a while he would turn his face back with an expression of happiness and triumph. As for myself I had, of course, a feeling of satisfaction, and the huge, steady machine was pleasant to ride, but I was busy with the controls trying to do the important job correctly.

Having reached some 400 feet, I started to turn to the left. The plane performed nicely. A little later, a second turn at some 600 feet altitude was made, this time passing over the hangars and the point of departure. The mechanic on the front bridge was happily waving his hand to the huge crowd below, the co-pilot behind in the large cabin was looking down through the window. For a short moment a happy realization that this was the long-desired achievement flashed through my mind. The next instant, however, I was again busy with the routine test flight. Having enough altitude, and flying over open fields, I could test out the controls more extensively. The plane reacted well, but much more slowly than a small one. Next, I put my hand on one

of the throttles and started to pull back very carefully, pushing the rudder pedal at the same time. The engine may not have been throttled down entirely, but it seemed clear that this could be done and the plane would still remain under control. Finally, it was possible to make what appeared the most important item of the test, namely, the "landings." While still some 700 or 800 feet high, I tried twice to put the plane in a gliding position, and then by pulling the wheel reproduced a manœuvre of normal landing. The plane obeyed so satisfactorily that, contrary to the original programme, I decided to make an ordinary landing and not a power stall. About one mile from the field, I turned round and started to come down gradually, aiming at the beginning of the runway. The plane was well under control and having reached the field at an altitude of some fifty feet, I could increase the power slightly and continue to fly over the runway towards the hangars. Having reached the middle of the runway, I cut the engines and easily made an ordinary, reasonably smooth landing. The huge plane came to a stop.

Engines were left idling while the mechanic went out to inspect the landing gear before taxi-ing the remaining distance. The mechanic climbed back into the ship.

"Everything seems to be in order."

At that time, however, it was obvious that we could not taxi, and must quickly stop the motors. Parallel to the runway at the edge of the field on a high embankment a huge crowd had collected during the last few evenings. The size and the unconventional appearance of the plane created some interest and ex-

citement. The people were usually very orderly and never invaded the runway. That evening, however, after the first flight of the "Grand," it was different. A few moments after landing we glanced through the window and saw in the dusk that the whole borderline of the field was moving like a tide towards the plane. Thousands upon thousands of men were running towards the ship and a moment later the "Grand" was surrounded by the crowd, roaring and shouting their joy. All three of us stepped out on the balcony waving our hands and hats, thanking them for this unprepared and sincere expression of approval and enthusiasm.

Since moving the plane was impossible, I decided a few minutes later to step down and walk towards the hangars. Before I could reach the ground I was grabbed and carried all the way towards Mr. Shidlovsky, who was also happy and jubilant, waiting to receive my report of the test.

This short flight of less than ten minutes' duration that evening of May 13, 1913, was a very important event in my aviation work. It confirmed practically all major claims that we had made, and that were so frequently questioned with respect to the large plane with several motors.

During the next few months, the ship made a large number of flights, and became a familiar sight over Petrograd. It was named "Russian Knight," but somehow the short nickname of "Grand" remained more popular. The tests furnished a large amount of data. All the flight and control characteristics were satisfactory, in spite of the size. The deficiencies of the plane soon became known, but they were not

serious and were not caused by the size or general layout.

The large rudders proved to be not only adequate, but indeed had more than enough power to hold the ship on a straight course; even with two engines on one side stopped. The most important defect of the plane was a poor take-off and climb. In order to keep the engines close to the centre line, they were mounted in two tandem groups on both sides of the fuselage. This was done chiefly to protect the plane from the danger of unsymmetrical thrust if one of the outer engines should stop. The tests, however, showed that there was a large margin in directional control, but the propellers working one behind the other apparently did lose their efficiency, particularly during the take-off. After heavy rains there were times when the "Grand" would be unable to gain enough speed to leave the ground.

To remedy this and to obtain reliable comparative data, the plane was altered in June, 1913. The two rear engines were taken off and mounted outside on the leading edge, transforming the installation into a four-in-line. It was very interesting research because it permitted us to compare the results of the two different installations on the same plane. The change resulted in a substantially improved take-off and a slightly better climb. The rudders were still effective enough to hold the plane against two engines stopped on one side. The flight of the plane in general was smooth, and the change of the direction of flight was in itself slow. Therefore, even a complete and unexpected loss of an engine would not disturb the stability of the plane. Much other information was

collected during these summer flights and formed the basis of a project for the next large plane to supersede the "Grand."

Early in July, a message was received informing us that His Majesty the Emperor had expressed a desire to inspect the plane during the Army manœuvres in Krasnoe Selo. Proud and happy, I took off in accordance with instructions, and landed early in the morning on the appointed place on the large Army field near Krasnoe Selo.

The military manœuvres lasted until the early part of the afternoon. Soon afterwards, the Emperor came up to the plane, followed by the Grand Duke Nicholas, and a few officers of the suite. The Emperor first went round the ship looking it over. I followed him and, as was the custom, did not speak, but only answered the questions that were asked. I was surprised to find that the Emperor was among the very few persons who did not ask questions unless they were correct and intelligent ones. All the queries were reasonable and sound from an engineering point of view. Having looked the plane over from the outside, he expressed a desire to see the cabin. There was nothing available except an old ladder which, by the way, was far from being clean or in good condition. The Emperor said, with a smile, that it would do and climbed on to the front bridge. I was already there holding the ladder and when he entered, I followed into the cabin. While there, I maintained conversation without any restrictions, as one would talk freely with a friendly person. Various details of the plane were discussed. Finally, the Emperor stepped out again to the front bridge, expressed his thanks for the work done, climbed

down and soon afterwards left. I remained near my plane, holding firmly in my memory the details of this meeting, greatly impressed by the simple, kind and extremely attractive personality of my high visitor. Following that event, I received later a personal present from the Emperor, a gold watch with the imperial eagle.

The demonstrations and test flights of the "Grand" were continued during the summer and early fall. Various measurements and observations were made during that time to secure design data for the next large plane. On August 2nd the ship made a flight of one hour fifty-four minutes, establishing a world record for duration with eight persons on board. This very modest load was at that time not much below the maximum that the ship could carry.

In the middle of the summer we had to take the "Grand" out of the hangar and leave it outside, the space being needed for the S-10 and S-11, the new military bi-plane and monoplane which were completed during July, and which were to participate in the Army competition in the Fall of 1913. It was important to have these ships in excellent condition for the meet and we had no extra hangar space. The fabric covering, treated by the old method, suffered from the rain and the plane lost badly in performance. During one of the last flights in August it was possible to reach only 2,500 feet altitude with eight persons on board.

I realized that by covering the wings with new fabric and fixing some ribs that had become warped, performance could be restored, but after all the plane

had done its job and I left it as it was, continuing to fly it from time to time.

During the month of August the military competition again got under way. I did not fly any of my ships this time, but the two pilots of our company flew the S-10 and S-11. Among our competitors was Mr. Gaber-Vlinsky, with whom I had had such a close race the year before. During one evening late in August, I was walking from the Administration building towards the hangar. The "Grand" was standing outside surrounded by an eight-foot fence. I stopped within two or three hundred yards from the big ship to look at Gaber-Vlinsky, who was flying about 1,000 feet high on his pusher bi-plane. Watching the plane, I could see that something had gone wrong. I heard a distinct cracking noise, noticed pieces flying away and a moment later saw a large dark object falling from the plane. I soon recognized the engine with the middle part of the propeller. I watched it turning and falling until it hit the ground, apparently very close to the "Grand." I started to run towards the place where his plane was gliding. Somehow, Gaber-Vlinsky succeeded in getting down safely, in spite of the fact that the elevator controls were damaged. And when the plane crashed in a ditch on the side of the field, by some exceptionally good luck, Gaber stepped out unhurt. I found him saying very excitedly what he thought about his plane. His speech was convincing but unprintable. Only after he had stepped out of his cracked-up plane did he learn with great surprise that the whole motor was gone. While in the air he had heard and felt that something was going to pieces behind him, but he thought it was a propeller

breaking. Returning to our hangar, I saw that the engine had fallen on the wing of the "Grand." It had crashed through causing serious damage. I decided not to repair the big plane and ordered it to be disassembled. The "Grand" had made altogether fifty-three flights without the slightest trouble until its career was terminated by this strange accident.

XI

A BIGGER AND BETTER FOUR-ENGINED PLANE

THE military competition of that year was again completed successfully. Our pilots, Gleb Alechnovich and George Jankovsky, flying the S-10 and S-11, won the first and second prizes. Some orders were later received for a modified type of the S-10 plane. The factory had to be enlarged to take care of this work as well as of the construction of the four-engine transport which was started during the month of August. This second ship was substantially larger than the first one; it had a wing span of 102 feet, a wing area of about 1,700 square feet, and an estimated gross weight slightly in excess of 10,000 pounds. It was to use the same four Argus motors of 100 h.p. each. In spite of no change in power and a greater weight, improved performance was expected as a result of more efficient design. The ship had bigger and better shaped wings, a greater gap both between the wings, and the fuselage and the upper wing. Finally, the fuselage was larger but was improved in form. The front part of it included a roomy pilot's cabin. Behind the seat was space sufficient for a few persons to watch the controls in flight. Openings on both sides permitted the mechanic to climb out on the wing and reach the motors. A floor

hatch on the left side provided an exit towards the front balcony or bridge. Behind the pilot's compartment was a roomy passenger cabin, with four large windows on each side. Further to the rear ran a passage with the entrance door, a stairway to the upper bridge and a door to the washroom. Further back, below the bridge, was a private cabin with a berth, a small table and a cabinet. The plane was lighted by electricity, the current being provided by a wind-driven generator. Heat was supplied by two long steel tubes situated in the corners of the cabin through which passed part of the exhaust gases.

There were still many struts and wires, a large number of exposed parts, as well as two balconies; the one in front about four and a half by six feet, clearly seen in the photograph, and another of still larger size situated on the top of the fuselage, some fifteen feet behind the wings. The ship was completed, transported to the hangar and assembled there at the end of December, 1913. This plane was named " Ilia Mourometz " in memory of a popular Russian legendary hero of the tenth century.

The month of January in Petrograd was usually cold with plenty of snow and, therefore, the big plane was mounted on wide wooden skis covered with steel sheets. Contrary to all expectations, however, the weather early this January was very mild and all snow melted away except in the ditches. That was indeed a disappointment, because the wheel landing gear was not ready and having ordered special rims and tyres we could not expect to get it for a long time.

On one of these days, Mr. Shidlovsky approached me with a worried look on his face.

"Can't something be done, Sikorsky, to avoid delaying these tests any longer?"

"In my mind," I answered, "there is no danger in attempting a take-off, except that if the plane should fail to lift, it would probably get stuck in the soft ground. It would be rather difficult to dig it out."

"That ought not to stop us so long as there is no danger to the men on the plane," he said. "Let's make the attempt."

The runway was very wet, practically free of snow, and covered with pools of water. Snow was brought from the ditch and distributed in two narrow lines about fifty yards long, and as wide apart as the two skis of the plane.

I entered the pilot's cabin, willing to do my best to carry out the scheme, but to confess the truth, I expected to get stuck about half the length of the runway, which looked like a swamp. Before starting, I opened the engines wide and checked the full power, and then gave the sign to push the plane ahead. The ship started to accelerate very quickly along the snow paths, then it went on the wet grass and continued to skid along. At times it slowed down, but when pools of water were encountered it gained speed, and so gradually to my surprise it began to move faster and faster. With the tail reasonably low, the ship finally took off. The flight was only of a few minutes' duration because the plane was extremely tail heavy, but it proved the full possibility of using skis on the wet grass provided we had a little snow for a start. We also learned that after landing it was necessary to open the engines almost immediately, and not permit the plane to slow down. Otherwise it would stop, and would not start again

even with full power unless several loads of snow were brought and spread over the ground.

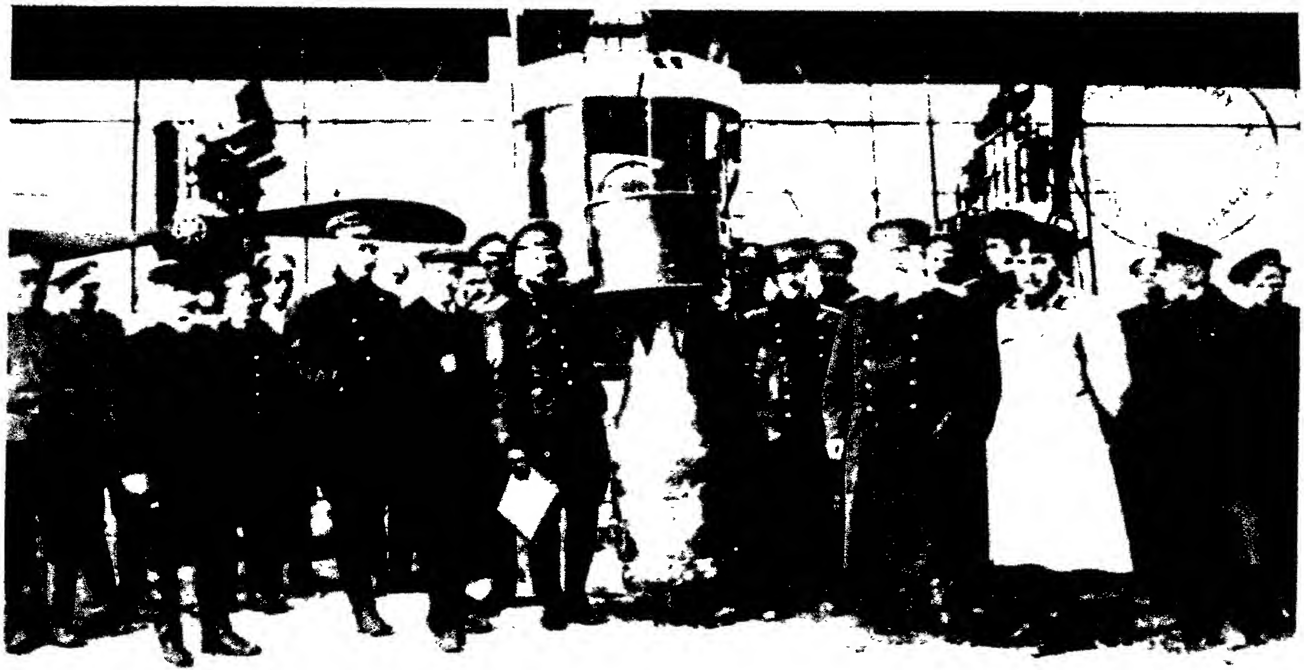
The tail heaviness was corrected and various other minor adjustments were made, and late in January the plane was in good order and quickly demonstrated the fine characteristics of the four-engined type. While the "Grand" showed the possibilities of such aircraft, in the "Ilia Mourometz" these distinctive qualities became a reality. During February and March, 1914, the plane made a large number of successful flights. On February 11th, it took off with sixteen persons on board, making a new world record for the greatest number of passengers. A few other world records were established, but more important were the vital engineering results that were achieved. This plane marked the end of a period of experimentation. While there was obviously a road open for further refinement in almost every respect, yet the "Ilia Mourometz" was a serviceable transport aircraft ready for practical use.

During the months of February and March the flights created much interest in Petrograd. A large number of visitors began to come to the field to inspect the plane. Many members of the Government, as well as of the Douma, visited the ship on their own account and at the invitation of Mr. Shidlovsky. He was glad to show this answer to the critics and doubters who had predicted failure. The old aeroplane box with windows and a stove was again placed in service. This time it was arranged as a tea-room. When waiting for a flight, it proved to be an excellent place to spend the time with a glass of tea and the friendly and cosy noise of a samovar. This aeroplane box, due to its proximity to interesting work, became in some respects a strange

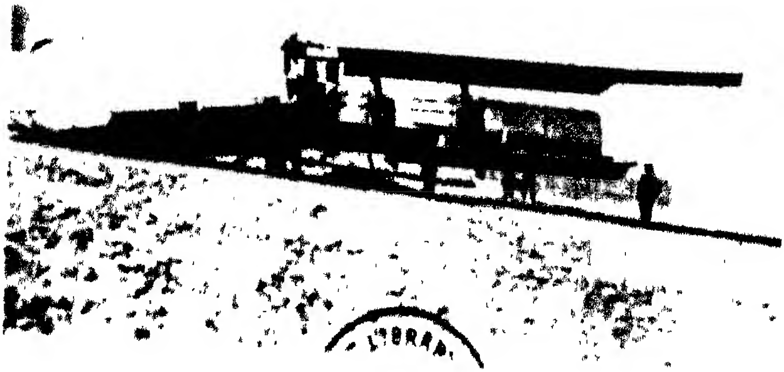
place. At times we saw a Cabinet Member of the Imperial Government, calmly and peacefully discussing flight impressions with some of the Leftist members of the Douma. A person familiar with the state of mind in Russia at that time would have realized that this, unfortunately, was not the usual thing.

The extensive demonstration of the plane happened to be a useful way of dealing with some fair-minded people, who for some reason were still doubtful or unfriendly. I remember once being called out from the hangar by a visitor, and when I stepped out I met a man who informed me that he was a member of the Munitions Committee of the Douma and that he would like to see what was going on. I felt at once that my visitor was somewhat critical, but I pretended not to notice that. I showed him around for a few minutes and pointing to the tea-room asked him if he were cold, and then begged to be excused, saying that there was a flight scheduled within an hour and that I would have to attend to some work beforehand. I left my visitor alone, to his apparent satisfaction. He walked around, talked with the mechanics, and later watched the preparations. A few days later he came back again and accepted an invitation to fly. Afterwards he became a frequent visitor, often bringing other members of the Douma with him. This man, Mr. I. F. Polovzev, soon became a sincere friend and often gave us welcome assistance.

Friendly help was still needed upon a number of occasions. I mentioned my extremely good luck in having assistance and encouragement for my work from members of my family and later from Mr. Shidlovsky. When I signed the contract with the Russian Baltic



A group of officers of the squadron and a 1,000 pound bomb
Second to the left of bomb, the author; second to right, General Shidlovsky



"Ilia Mourometz X" damaged by anti-aircraft fire

The machine gun cockpit at the rear end of the fuselage on "Ilia Mourometz" ships in 1916

Works and was ready to leave for Petrograd from my home town, my father called me into his room and gave me his advice and warning.

"My philosophy of life is idealism and optimism, but in spite of that, as a psychologist, I wish to caution you that for some reason success, besides calling for approval and praise, usually creates envy and hatred." Time and time again I realized the profound wisdom of his statement of the elderly scientist. I can see now that aerodynamic drag is much easier to take care of than other types of parasite resistance which often slow down progressive work.

The flight demonstrations and tests were continued successfully during March and April. Being well acquainted with the plane, we could now fully test its characteristics. We could stop one, and even two, motors, send one or two men on the wing and change the spark plugs on the outboard motor, climb nearly to the end of the fuselage. It was also possible to fly in bad weather. In April the Navy became interested in the plane and we started to prepare pontoons to test the ship from water. At the same time, during April, the second "Ilia Mourometz" was completed and transported to the field. This ship was identical with the first one except that the engines were more powerful. These inboard were 140 h.p. and the outboard 125 h.p. With greater power and slightly cleaner engine installation, the new ship developed a much better performance, which was enthusiastically received by the growing number of friends of the "Ilia Mourometz" type.

The opposition was still keen, however. The curious fact was that when the basic principles that were so definitely declared to be incorrect and impossible,

were finally successfully demonstrated in flight, almost immediately new points and proof were found to discard the idea of the large plane. Early in May, there was a telephone call from one of our friends from the Douma. He said that a certain aviation expert had informed a group of influential members of the Douma that the planes of the "Ilia Mourometz" type were too big and heavy for high flying. He explained why he thought this was the case, and as final proof mentioned that our ships never climbed much higher than 1,000 metres (3,300 feet). Therefore he concluded that planes of such type would have no military value and very little commercial usefulness. My friend was somewhat discouraged by this talk and finally asked me what I had to say about it. I replied that I had nothing to say and instead invited him the same afternoon to come with us on an altitude test. I suggested his bringing some of the deputies who were present during this discussion.

That evening we took off with twelve men on board. Among them was my friend and four other members of the Douma. Making wide circles, the ship gradually climbed to 2,100 metres (6,900 feet). This was considered a sufficient altitude for heavy bombing planes of that time. By such a demonstration it was possible to turn even adverse criticism in our favour. The Army became more interested and a discussion was started on the subject of ordering several ships of the "Ilia Mourometz" type.

There was one more important test flight as well as demonstration left to be accomplished, namely, a long journey across country. Until then all flights had been in the neighbourhood of Petrograd, never more than

forty miles away from the airport. As a test of the fuel consumption, we made a longer flight on June 18th. The ship, with seven persons aboard, remained in the air for 6 hours 33 minutes, establishing the world record for duration for an aeroplane with six passengers. The plane was in good order and it could have been loaded even more heavily. After this test, I decided to make a flight to Kiev, my native city, in order to test and demonstrate the ship in a long flight.

XII

THE FLIGHT OF THE "ILIA MOUROMETZ" TO KIEV

SHORTLY after midnight late in June, I arrived on the field. The other members of the crew were already there. They were Lieutenant Lavrov, who acted as navigator and co-pilot; Captain Prussis, second pilot, and my mechanic, V. Panasiuk. The plane was loaded more than ever before. Besides filling the tanks to capacity, we took additional fuel and oil in containers which were placed in the cabin. We also brought pumps and hoses to send the fuel from the cabin containers to the main tanks, as well as an extra propeller, various spare parts and tools. The night was clear, with no wind. We checked the fuel, looked over the plane and then went into the cabin and started the motors. About 1 a.m. the horizon became visible. In order to adjust the engines carefully for full power we placed in front of the wheels some blocks which were just thick enough to hold the ship with engines running at full power, while some twenty men stood behind the wings. We went into the cabin, the engines were started, and in a few minutes they were warm enough so that I could move the throttle lever to full power position. Using a flashlight I looked over each of the four tachometers and then gave the signal. Pushed by

some twenty men, the overloaded plane rolled heavily over the beams and started moving along the runway. It was impossible to see the ground but I was able to hold the direction, as I could see on the horizon some familiar landmarks. The ship took off after a long run and started to climb slowly. With engines running wide open we hardly reached 500 feet during the first fifteen minutes of flight. It was still dark during the first hour after the take-off. There were no lights on the instrument board and from time to time we used a flashlight to look over the instruments. At such times the cabin was lighted up but we could see nothing outside. Gradually, after 2 a.m., it grew brighter. The flight was extremely smooth. The plane slowly gained altitude, chiefly because it became lighter as fuel was consumed.

Around 2.30 a.m. we reached about 2,000 feet. The engines were now working slightly below full power. The weather was excellent and the air smooth. Each one of the pilots spent half an hour at the controls, otherwise there was not much to do. Twice during this flight I climbed on the wing towards the outboard motor. There was no actual necessity for doing this because the engines worked well, but I wanted to be sure the engine could be repaired in the air. Behind the motor there was a space reasonably protected from the air stream. It was beautiful and interesting to watch from this point the huge body of the ship and the wide, yellow wings. It was a strange feeling to see these wings apparently motionless in the smooth, clear, and cool air of the early morning.

Another two hours passed. Flying steadily at an altitude of 5,000 feet, we pumped the spare fuel into

the main tank and cleaned the cabin of petrol containers. Around 7 a.m., while Captain Prussis remained at the controls, the rest of the crew got together in the large cabin. The table was covered with a cloth and a regular breakfast consisting of fruit, various sandwiches and hot coffee was served. We believed that this was the first time that meals were properly served on board a plane while in the air. We all enjoyed the food, sitting in large, comfortable wicker arm-chairs around the table, with glasses of coffee.

The visibility was excellent and navigation was simple. Shortly after eight o'clock we passed Vitebsk. In the remarkably clear air of the morning the city looked attractive and interesting with its streets, houses, a large, busy market-place, and a number of churches with bright golden domes.

While over Vitebsk, we sent two telegrams, one to my home and the other to the factory. In order to do this we would place a written message, with the necessary money and a small tip, in an eight-inch piece of aluminium tube stoppered at each end with a cork. We also enclosed a note asking that the message be sent as soon as possible. Around the tube there was wound a long tape of bright cloth. When thrown out the cloth would unwind and make the falling tube visible. We dropped several messages in this manner during the trip, and each one was found and sent.

Soon after nine, we saw ahead of us the town of Orsha, and without any trouble located the field marked for our landing. I throttled the engines, and as we descended to a lower altitude the air became more bumpy and finally very rough below 2,000 feet. I landed, taxied towards the barrels of petrol, which I

could see in one corner of the field, and ordered the ship refuelled.

When we stepped out we were surrounded by a large and enthusiastic crowd. We received fresh fruit and various presents and were asked a multitude of wild questions. With some difficulty Lieutenant Lavrov and myself succeeded in getting away to inspect the field and make plans for the take-off. The strip of land which our engineer chose for the landing was about 150 feet wide and some 1,200 feet long. The field was flat and hard, but the length was not any too great for the heavily overloaded plane. At one end there was a grove, while at the other a precipice yawned about 100 feet deep, with the river Dnieper at the bottom, and the city of Orsha situated on the opposite bank of the stream. It was a hot summer day and a very light wind was blowing from the grove towards the river. There was also a gentle slope in the same direction. Having analysed the situation, we decided to make the take-off down-wind towards the river. When we returned to the ship around noon, we were disappointed by the slow progress in refuelling. The energetic efforts of many volunteers could not overcome the low capacity of the few petrol pumps which had been rented in the vicinity and almost one half of the 400 gallons of fuel was still in the barrels. As the time went by we became somewhat disturbed, because we had no equipment and no experience in night flying at that time. The trip to Kiev would take another six hours and the nights in the south are dark, unlike the "white" nights of northerly Petrograd.

It was about 2 p.m. before the refuelling was finally completed. With the assistance of some fifty

men the plane was pushed towards the very end of the field and turned round. It took practically no time to warm up the engines on this hot day. In accordance with instructions, a group of young men, whom we had picked out from the crowd, pushed the plane across the blocks and continued to run and shove it as long as they could keep up. The heavily overloaded ship gradually gained speed. With the control wheel slightly forward, I watched the approaching precipice at the end of the field.

We had all kinds of good wishes for our motors, because if even one should start missing it would be bad indeed. In order to gain all possible speed, I made no take-off at all. I permitted the heavy ship to run all the way, and off the end into the ravine. The plane dropped down slightly but gained a little more and remained in the air. The Dnieper was crossed at about the level of the field, and I continued to fly level just above the roofs of the houses. After crossing the city we began to gain altitude, and I turned south. A minute or two later we got into trouble. It was after 2 p.m., the day was hot and along our way there were fields, forests and swamps, which caused different currents, and as a result the air was extremely bumpy. We reached some 250 feet altitude, when a rough air gust threw us down to less than 100 feet. I ordered the three cans of spare water and one can of oil to be thrown overboard. Whether the result was mechanical for the plane or moral for the crew I do not know, but somehow I succeeded in staying in the air. Flying was extremely difficult. The overloaded ship with very little excess power could not gain altitude. When, after a few minutes of careful piloting

with all four motors at full power, we would reach 400 to 500 feet, a rough air-pocket would again throw the ship down to some 200 feet or less. It was stifling hot in the cabin. I was tired after only fifteen minutes of this and I could not get any higher than a few hundred feet. I asked my mechanic and Captain Prussis to stay in the main cabin and to be ready for my order to throw overboard cans containing petrol and, if necessary, spare parts, because all the water and extra oil were already gone.

A few minutes later my mechanic rushed into the pilot's cabin. Glancing at his face I realized that something was seriously wrong. He was pointing to the rear of the right inboard engine. Looking in that direction I saw the cause of his worry. The petrol tube was broken through a few inches from the carburettor, and the fuel was streaming out.

The engine was still running at full power during that second, but before we could do anything it started backfiring a couple of times, and before it went dead the exhaust flame, or possibly the backfire, ignited the petrol leaking out of the pipe. A huge flame about twelve feet long sprang out, touching the surface of the wing and encircling the wooden strut.

Lavrov and Panasiuk quickly climbed out on the wing and began to fight the flames with their overcoats. Lavrov stepped on the engine frame and, bending over the still strong flame, reached the shut-off valve and closed the fuel line. After this, working furiously with their overcoats, the two men finally succeeded in checking the fire.

We were less than 400 feet high, flying over woods, and the overloaded ship, with one dead motor, was

now losing altitude. I made a complete turn and pointed the ship in the direction of a small field which I remembered seeing a few minutes before the fire started. Flying on three motors and steadily descending, I was able to bring the plane towards the field and make a good landing.

During the petrol fire none of us had apparently been frightened. I continued to control the plane in rough air, watching my friends on the wing who were doing their job in a business-like way. Everyone expected a more serious development at any moment. But once we stepped out safely on the ground to inspect the blackened struts and burned wing, all exactly below the huge petrol tank, we became somewhat "nervous." Smiling, and congratulating each other, we realized that this had been a narrow escape.

The mechanic brought his tools and spare parts and started to fix the petrol line. We looked over the field which was a narrow strip with a considerable slope towards a brook, and flat swampy pastures around it. We decided to take off down-hill, irrespective of wind direction. In less than one hour the plane was again ready, but it was too late to start. There was not enough daylight left to reach Kiev and we decided to stay overnight. By that time a large, friendly and excited crowd had already gathered willing to offer assistance. With the help of the men we pushed the ship to the end of the field, turned it round and placed it in the proper position. Lavrov and myself accepted a dinner invitation from the local Chief of Police, while the two other members of the crew stayed with the ship. We were treated royally, but disappointed our host by declining to take even a single drink of vodka.

By ten o'clock that night we returned to the plane. The other two men informed us that they had made a thorough inspection of the plane, and found that except for the burned fabric and paint, no damage had been done. They also said that the local peasants brought enough food to last for a month. Their only trouble was answering hundreds of questions, some of which were perfectly fantastic. One of the fellows wanted to find out how could the huge wing flap in the air, another wanted to know how the plane could land on a tree or on a smoke stack, and the next one asked where they put the lifting gas in this dirigible! The night was cloudy and very dark as we went to sleep on board the plane. I used my own berth in the sleeping cabin, the first berth ever built into an aeroplane. About midnight drops of rain began drumming over the fabric of the fuselage. We got up before daybreak, and about four o'clock I ordered the motors started. At that time it was not raining, but heavy low clouds covered the whole sky and the morning was gloomy and dark.

Shortly after four, all motors were warmed up and soon everyone was at his post. The heavy ship started with some difficulty its run over the soft, wet field, but the steeper part of the slope helped and before the end of the meadow was reached we took off. There was no wind and the air was calm. The ship slowly but steadily gained altitude. We were slightly over 1,500 feet high when the city of Scklov was passed. We saw very little of it, however, because of the weather. Flying almost directly southward and gradually gaining altitude, we soon found ourselves in the clouds. It grew darker. During the first hour of flight it was

smooth, and even flying blind in the clouds was not difficult.

Then the weather began to change for the worse. The rain started again, and the air became rougher and rougher. With no experience in blind flying, I had a hard time controlling the heavy ship in rough air. I might say that with the instruments we then had, I would not now fly blind, I would not even go up with them in bad weather. But then they were all we had; they had been extemporized to meet a need, and better instruments came in time with better aeroplanes. At that time we were pioneers, we used what we could and were grateful for any little aid that we could get.

Lieutenant Lavrov came to my assistance and took over the navigation. He watched the compass, and pointed out the course to hold. I tried my best to fly the heavy ship, and with difficulty we reached an altitude of 2,500 feet. By this time the rain had become a real downpour. I worried about the motors, which were mounted entirely in the open, with the magnetos and wires exposed to the rain. However, they worked very well.

About six-thirty we were still flying blind in a very strong rain and rough air. Using full power, we could get only about 3,000 feet altitude, and every time a few hundred feet more were gained a powerful air gust would cast the plane down again. Once, after a minute or two of relative quietness, we felt a violent blast which threw the left wing down. Tired by the rough, blind flying, we did not realize at once what was going on, but we knew that something had happened, and that the plane was losing its normal

flying position. We felt that in addition to the left wing, the nose had also turned downward. The hand of the compass had apparently become detached and made a couple of complete turns, while the altimeter showed a loss of 1,000 feet within a very short time. To confess the truth, I had lost all sense of direction of flight. The controls appeared loose and the ship did not obey the ailerons. Now, I know what had happened. The ship had gone into a spin, as we call it, because of lack of proper flying instruments and the sudden gust of air, and was spiralling, nose down, towards the earth. Instinctively, I must have done the only thing which will bring the pilot from such a spin—neutralized the controls and let the plane pick up speed and come out of its own accord. I succeeded in straightening out the plane again after a loss of more than 1,200 feet of altitude. I found out later that I was not the only one at that time who thought our ship might keep right on falling until it crashed into the ground. That was my first experience with a spin, which everyone who has been to an air show has seen as a simple manœuvre. When done deliberately, and with sufficient altitude, in clear weather, it may be a pleasant experience to the pilot who enjoys acrobatics, but to us it was not only a novel but somewhat perturbing incident, particularly as we could see nothing, and did not know what was happening.

The ship came out of the spin entirely off the course. It was still very bumpy and raining hard and we could not see 100 feet ahead. Obviously in that rough air we would not be able to climb over the heavy rain clouds, so after a brief discussion with Lavrov, I decided to come down and continue the flight, if

possible, below the clouds, where we would at least see something. Those who now travel in transport planes can hardly imagine what we were about to attempt. I do not wish to over-emphasize the danger of the situation, but it was one which shows by contrast the tremendous progress which has been made in cross-country flying. Nowadays, a transport pilot can ask for the ceiling of the clouds at any point along his route, he flies according to the direction of a radio beam, and he knows thoroughly the topography of the country over which he is travelling. We had no such aids, and coming down was a process which required constant watchfulness and some degree of good luck. For all we knew, those clouds went to the ground.

The engines were throttled down. We watched the altitude, and looked ahead for a break in the clouds. At less than 800 feet, when we were becoming somewhat uneasy, we finally saw the ground in a haze through a screen of heavy rain. The green woods and pastures, barely visible through the downpour, offered no distinguishing landmarks by which we could locate our position on the map.

"I am convinced," declared Lavrov as he pored over the chart, "that we have gone off our course to the east."

"How much?"

"Well, I think we've been off it for the last twenty minutes at least."

"What course do you advise now?"

"South-west."

The rain was very strong, but it was not so rough, and with the ground in sight, piloting and holding the course by compass was easier.

"Good work, George, there's the Dnieper," I cried as I saw a gleam of water which I recognized instantly as the great river. We changed our course again to the south and followed the river for a few minutes until we located ourselves on the map about half-way between Orsha and Kiev. We continued to fly for nearly one hour, staying as high as possible, about 800 feet, without losing sight of the ground. By that time it was not necessary to use the full power and the engines were turning easily at reduced throttle. We kept a straight compass course, but from time to time saw bends of the Dnieper and Lavrov was able to check the position of the ship on the map.

Around half-past seven, we decided to try to escape the rain. With engines wide open, the ship started to climb. A few moments later the ground disappeared and we entered the clouds. It was rough from time to time, but not as bad as before. Following the directions of Lavrov, I had not much difficulty in keeping the ship on its course in spite of the entirely blind flying.

With a substantial amount of petrol already consumed, the plane continued to climb. We exceeded 3,000 feet, and it was still raining. Gradually, the plane reached 4,000 feet. There was less rain, but the clouds closed in still thick. The ship mounted steadily. A few minutes later the rain cleared, and the gloomy darkness started to melt away. Around 5,000 feet the light began to increase quickly, and a few moments later the huge ship emerged from a layer of dazzling white clouds into the bright sun and beautiful clear blue sky above.

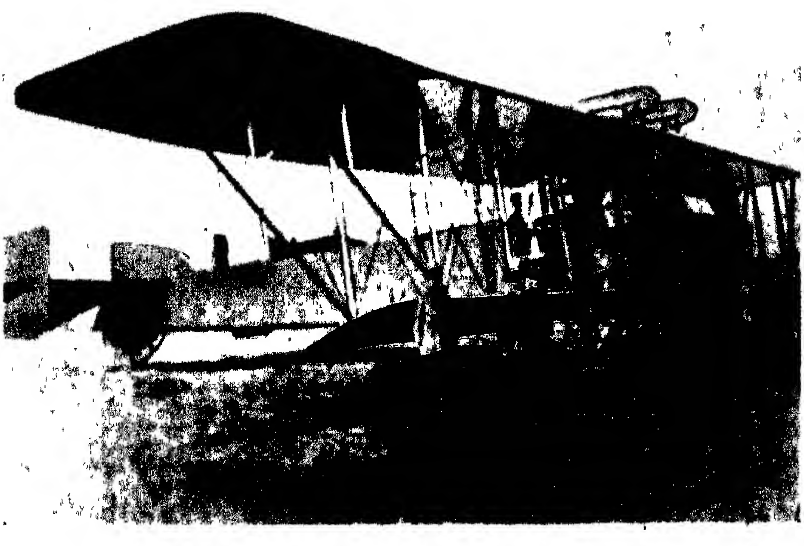
For a few minutes we all covered our eyes to pro-

tect them from the intensely brilliant light, until we gradually became accustomed to it. The conditions of flight were at once entirely different. Bumps and air gusts disappeared completely. The large plane was sailing now with such remarkable smoothness that a full glass of water could be left on the table without spilling a drop.

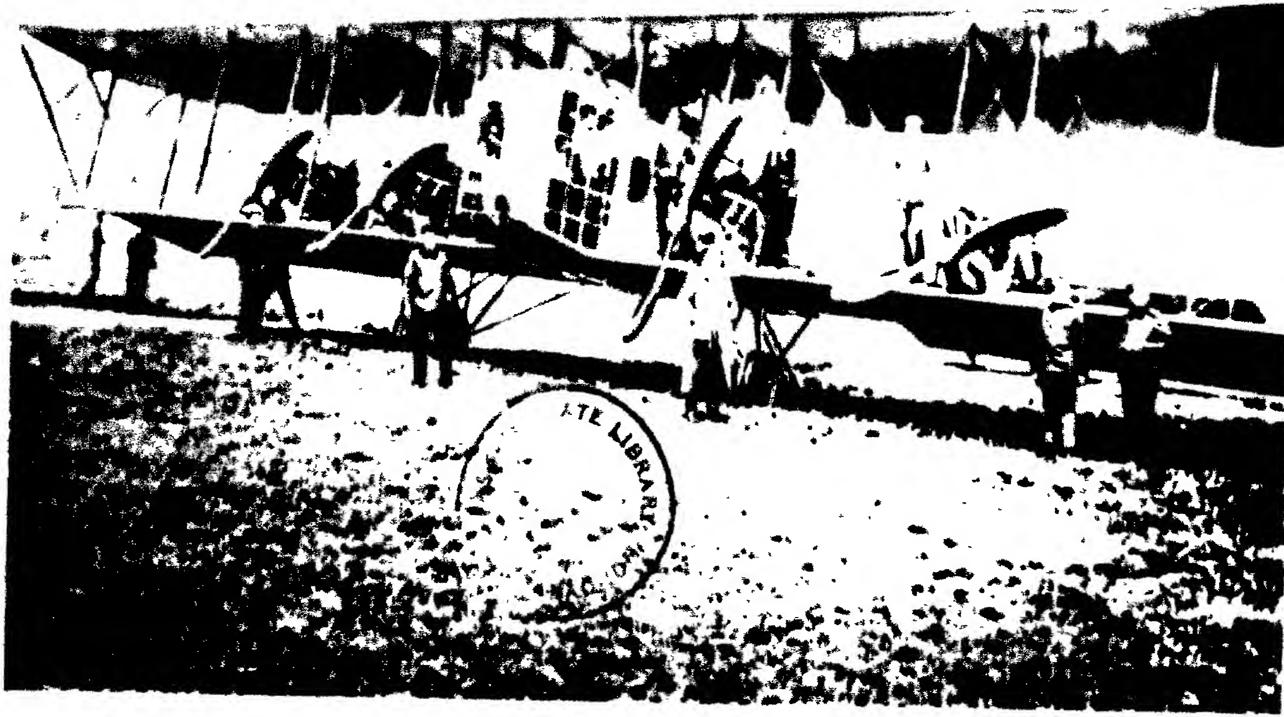
Captain Prussis now took over the controls. Lieutenant Lavrov, seated in a comfortable wicker chair, leisurely worked with the maps and papers, checking information about the remaining part of the route. We decided to stay above the clouds all the time and to come down only when we could expect to be above Kiev.

I drank a glass of coffee, put on my warm overcoat and went to the upper bridge of the ship. A fresh, cool wind compelled me either to hold on to the rails or to stand obliquely. Only a few times in my life have I seen such a majestic and beautiful spectacle as I did then. With the power of the engines reduced to slow cruising, our ship was gliding along a few hundred feet above a sparkling white surface. The air was calm and the plane seemed motionless with its huge yellow wings stretched out some twenty feet ahead of where I was standing on the upper platform. All around me there was a fairyland, formed by clouds. The surface was not at all even. From time to time the plane would pass close to a strange-looking mountain. Next there would be a gigantic mushroom several hundred feet high. When we passed close to it, the cloud motion below its huge head would become apparent and a few bumps would be noticeable. For a long time I stayed alone on the

" Ilia Mourometz C" with tail machine gun installed



" Ilia Mourometz C "



" Ilia Mourometz E "

platform admiring the wonderful fairy panorama—the strange beauty of which I will never forget.

Time and time again I have had chances to fly above the clouds in an aeroplane in most parts of the world, but the impressions of this flight were never repeated. This was not only because of the exceptional splendour of the scenery of that morning, it was also because of the sightseeing point on the upper platform. In fast, modern planes, looking through the window or even sitting behind the windshield in an open cockpit, one cannot see so completely as when standing entirely in the open, far behind the wings, on a narrow fuselage platform. Eventually, my frozen hands made it necessary to return to the cabin. I went down and took one of the comfortable wicker chairs near a window, and looked at a beautiful picture, but in the open I had seen and felt some majestic and strange reality.

The two hours of flight above the clouds were easy and uneventful. After the long, tiresome flying in the rainstorm and in the clouds, I was glad to leave the control wheel in the hands of Captain Prussis. Lavrov had faith in his navigation, and we desired to stay in the delightful and calm zone above the clouds until the ship neared Kiev. Finally, after about two and a half hours of flight without once seeing the ground, Lavrov informed us that Kiev must be about five miles straight ahead. I stepped into the pilot's cabin, took the controls, throttled down the engines, and started to descend. The brilliant white surface was now quickly approaching.

A minute later the plane descended into an unbroken sea of clouds. The bright sunlight and the

blue sky disappeared, dark quickly surrounded us. We entered the clouds at slightly below 5,000 feet. As the plane came down gradually, it grew more and more dark. It was not raining and reasonably smooth, but we got the impression of flying in a dense fog. Gradually descending we were still in that fog while the altimeter showed less than 2,000 feet. During the next couple of minutes we began to feel uneasy. Finally, at about 900 feet, the plane suddenly emerged from the clouds. Directly ahead and below we saw the golden domes of the Lavra Cathedral of Kiev, while to the left I recognized the well-known chain bridge across the Dnieper.

A quick turn, another few minutes of flight over the familiar suburbs of my home town and we were landing on the Kourenev Airport, the same one on which three years earlier I had made my first flight. Very few people had come to the field because our plane was not expected on that rainy morning. The Secretary of the Aeronautical Society of Kiev, however, was there. The first thing he said after congratulating us was to inform us that the Archduke Franz Ferdinand of Austria had been murdered in Serajevo. While not foreseeing the enormous historical consequences, we all somehow realized the seriousness of the event.

Kiev gave us a great and friendly welcome. For several days, crowds of people visited the airport and looked over the "Ilia Mourometz." Several flights were made carrying friends, city officials and others. My father was not very strong at that time and he usually stayed at home. A few days later, however, we procured a large closed car and drove him to the air-

port. I was particularly happy to demonstrate the plane in flight to him and he later said he was impressed by the smooth and steady flight of the large ship.

One evening during our stay in Kiev, air service officers arranged a dinner for the crew of the "Ilia Mourometz." It was a nice, clear summer evening. The party was held in the elegant garden house of the Chamber of Commerce, situated on the summit of one of the hills with an exceptionally beautiful view directly overlooking the Dnieper. It was a gay affair which lasted until daybreak.

But in my memory it is connected with sorrow. Many of the fine, young officers who attended this dinner lost their lives shortly afterwards. My brother was killed in a naval battle in the Baltic Sea about three months later. Another guest, Captain Nesterov, the first man in the world to make a loop in an aeroplane, died about the same time in one of the first combats in the air, having destroyed the enemy plane. Of the companions of our flight, Captain Prussis was killed in an aeroplane accident. Similar stories could be told about other young officers whom I saw for the last time during that dinner.

After a few more restful and pleasant days in Kiev, the "Ilia Mourometz" took off, early in the morning of July 11th, for the north, with a crew of only three men, because Captain Prussis had left earlier. About seven and a half hours later we landed at Novo Sokolniki, which was more than half-way. The refuelling was done very quickly this time because our representative had made an ingenious arrangement with compressed air whereby all tanks were filled in

less than three quarters of an hour.

About noon we took off. Part of this flight was again extremely difficult. The heavy plane could not climb high enough, and it was hot and extremely rough in the air. Farther north we entered into a zone of heavy forest fires which made conditions still worse. Gradually, however, as we used gas, we were able to climb higher and after reaching about 5,000 feet the conditions of flight became reasonably good. About four o'clock we observed a stream of petrol spurting from behind the left outboard engine. While Lieutenant Lavrov handled the controls, I climbed out to the engine. All four small screws holding the top of the carburettor had worked loose, two of them having fallen off. The petrol was streaming from the circular slot below the cover. I turned the two remaining screws as tight as possible, which cut off the leak, and returned to the cabin, happy to have another proof of the value of the basic theory of the large planes which we were trying so hard to introduce. About 5 p.m., we saw ahead of us the well-known black spot on the horizon, and soon afterwards we were flying over Petrograd. Tired but happy, I landed on the familiar runway of the military airport.

The 1,600 mile flight proved conclusively the value of large multi-motored aeroplanes. Even our mishaps helped to substantiate claims that had been made for the large ship. The Army placed an order for ten four-engined aeroplanes of the "Ilia Mourometz" type and the factory personnel was overjoyed by this final approval of the results of two years of hard work.

In the middle of July, I made a trip to Libava where the "Ilia Mourometz" No. 1 was being mounted

on floats. In spite of very little experience, basing the design of the floats on engineering common sense and intuition, I succeeded in producing reasonably good pontoons. They were made of wood, with the bottoms entirely flat, and the plane was connected with rubber shock absorbers to the floats to gain flexibility. I made several flights in Libava, taking off from the water in a ship that was at that time by far the largest seaplane in the world. The flexible suspension of floats proved to be successful; the plane moving smoothly even over choppy water, while the floats were bouncing and rocking.

I returned to Petrograd around the 20th of July to find the approaching storm apparent in the capitol. A considerable number of people did not want war. It would be more correct to say that no one wanted it. The government did not want it nor did the head of the government, Czar Nicholas II. There was, however, a definite and widespread conviction that the aggression against Serbia was not justified by a political assassination. In the past, Russia had suffered greatly from political murders that were organized and often financed from abroad; yet a war was never even considered as a result of these events. Therefore, the prevailing conviction was that if Serbia was attacked Russia could not remain indifferent.

The tragedy which began during the latter part of July is well known to all and needs no further comments.

During the two previous years, I had passed a good deal of time in September and October at the military airport of Petrograd in connection with the air meets. But although in 1914 I spent a large portion of my

time on the same field, conditions were very different. The months that went by brought hopes, disappointments, tragedies. The holiday atmosphere of the successful flights of the "Ilia Mourometz" was forgotten. I now had not only hard work to do but also the responsibility of training and checking out Army pilots who were to receive the ships and proceed to the Front. This was my work during the day, because at that time I had been for more than a year, the only pilot in the world to fly four-engined ships. While many fliers, and particularly Lavrov and Prussis, were familiar with the controls of the "Ilia Mourometz" in the air, yet none except myself attempted to take off or land the big ship. During the evenings I worked at the factory, completing the first five of the planes ordered by the Army, and installing armament, bomb racks, and other military equipment. Later in the night I worked at home developing a new type of large plane, especially designed for military purposes.

At that time none of my ships had participated in military flights. I realized that the huge planes with roomy cabins, but with slow speed and limited altitude, would not be successful for actual war purposes. Working late in the night, undisturbed by visitors or the telephone, I was developing in a hurry a preliminary project of my third type of large aeroplane to be known as the "Military Ilia Mourometz, Type V." The ship was designed around the same power plant. It was not as large and lighter, and it had a much smaller fuselage, and one single cabin properly arranged for bombs and military equipment.

Early in October I received a call from a Colonel of the Army Artillery Service.

"Will you take me up in the Ilia Mourometz one of these days? We want to test some new TNT detonation bombs on the proving ground near Petrograd. It will be more convenient to use the large ship because the bomb racks are not yet ready for the new bombs."

"Of course, Colonel, I shall be glad to arrange the flight."

On the same afternoon he came back to the airport with a small army delivery truck which carried the cases of bombs.

"Let us take six of the forty-pound bombs and one of the eighty," said the Colonel.

The cases were opened on the ground and then carried into the plane.

"We shall screw in the fuses before each bomb is dropped."

I looked inquisitive and he went on to explain.

"The fuses on this type of bomb are extremely sensitive and even a minor shock would cause the projectile to explode. Once the fuses are in, however, until the small propeller here in the rear of the bomb is unscrewed, the whole is harmless and can stand substantial shock without exploding."

We took off from the field and some twenty minutes later, approaching the proving grounds at an altitude of little over 4,000 feet, four forty-pound bombs were dropped over the proper section of the field. They all exploded as expected. I was curious about the procedure of dropping the bombs and asked Lieutenant Lavrov to take the controls for a while. I went to the cabin and watched with interest the throwing of the next bomb. The Colonel would take

it out of the box, screw in the fuse and then carry the bomb towards the square opening in the floor of the ship, lower it through the opening and let go. Dropped head down, the bomb would usually make one or two complete turns and then would straighten out in a more or less horizontal position and after a few oscillations, would become stable and gradually take a nearly vertical position. During the first couple of seconds we could easily see the little propeller start to whirl quickly and finally unscrew itself entirely and fall out. From that moment the bomb was sensitive and ready for action. I followed the progress of the hurtling object with interest seeing it clearly most of the time it was falling. It finally appeared like a small black point which seemed to be exactly on a vertical line under the aeroplane at all times. It was impossible to gauge the altitude of the bomb above the ground and finally after sixteen to eighteen seconds the small black point would instantly disappear and instead we would see a huge, reddish flame, and a big cloud of smoke and black dirt. The flame lasted only a moment, while the black cloud remained on the ground for quite a long while. About four seconds later we could hear a loud explosion, sometimes accompanied by a slight shaking of the floor of the ship.

After the last small bomb was thrown, the Colonel asked me to help him with the big bomb. It was somewhat bumpy in the air and we had some difficulty getting the eighty-pound bomb out of the box and carrying it towards the opening in the floor of the cabin. Within a few feet of the opening, we laid it down on the floor and while I held it from rolling, the Colonel took the fuse from the other box and screwed

it in place. Then we both lifted the bomb again and started to carry it towards the opening. While approaching a gust of air reached the rear part of the bomb, and before we could do anything we saw that the little propeller was beginning to whirl. A moment later it fell out under our feet! Both the Colonel and I realized what that could mean. We looked at each other, and without saying another word started to move towards the opening. I do not believe that a sick child was ever carried more gently and tenderly than we carried that huge bomb with the safety screw out. To tell the truth, I wondered several times whether I would be able to see the bomb go off should it decide to do so while it was still in our hands. Very carefully we transported the bomb to the opening in spite of the bumpy air, and slowly, and still more carefully, lowered it through, making sure that the fins did not touch the edge of the hatch. Then glancing at each other once more, we released the bomb. It fell out, and only a few seconds later, when it was already several hundred feet below the ship, we looked at each other again and smilingly congratulated ourselves. Some sixteen seconds later the bomb struck the ground, and produced a huge explosion with a big, bright red flame and a black cloud of smoke. A few seconds later the sound of the shock, together with the air wave, came up. We could easily hear it in spite of the noise of the engines, and we could even feel the shock against the bottom of the cabin, although the ship was at that time more than 4,000 feet high.

Mr. Shidlovsky left Petrograd in July and did not return until October.

I visited him on his arrival and after making a complete report said:

"I want to recommend urgently the speedy construction of the new type of large bomber."

"There is no question in my mind that you are right," replied Mr. Shidlovsky. "Design and build three of the new planes as quickly as you can."

The idea that work was usually done slowly in Russia is not correct; at least it was not true then. With the factory operating twenty-four hours a day in three shifts, with the engineering department working indefinite hours, practically as long as men could efficiently stand it, the construction was pushed ahead at full speed. The hum of the factory was continually in our ears as we laboured, largely with wood, as the planes were built of American spruce and pine.

During the daytime, I personally worked under a heavy pressure of numerous personal contacts and telephone calls, and always confronting many difficulties. This was a great time to learn the current problems of a large factory, but there was no time to solve them. That could be done mainly during the night. With a large pot of strong black coffee on the corner of my table, and the repeated use of a small cup, I could concentrate without being disturbed, and usually was able to prepare my part of the planning so that the progress of the work was not delayed.

The plane was designed, and several structural and aerodynamic tests were completed; then the ship was built, transported to the airport, assembled, checked and finally test-flown. From the time I received the order to start the preparation of drawings to the day when the new "Ilia Mourometz V" made its first

flight, exactly seven weeks went by.

With the same four engines, and similar lifting capacity, the new plane was almost twenty miles faster and could reach an altitude of 10,000 feet with full military load, instead of the 6,000 feet of the previous type. This was very satisfactory for a heavy bomber of 1914.

While this work was in progress, the two first ships of the old type left for the Front. Both planes were unsuccessful. One was damaged in a bad landing before it arrived at its destination while the other reached the Austrian Front and after a few weeks of test flying was pronounced to be unfit for use over the enemy territory because it could not reach sufficient altitude. The staff of the active Army wrote in a report advising that no more large planes be sent to the Front, and that motors and materials available be used for the construction of single-engined ships of conventional size.

XIII
THE SQUADRON OF FLYING SHIPS

THE future of our large planes seemed dark at that time. The situation was saved, however, by Mr. Shidlovsky. After spending a few sleepless nights, he prepared a complete report outlining the whole situation, and proposing definite steps in order to prove the military value of the ships. The report was addressed to the Secretary of War Souchomlinov, who in turn was expected to submit the information to the Emperor Nicholas II and ask for his approval of the proposed programme. The contents of Mr. Shidlovsky's report were briefly as follows: It was admitted at first that the staff of the Army were right in their severe disapproval of the service rendered by the first two ships. Next, it was explained that their failure was due partly to the limited performance of the planes of the old type, but chiefly because the crews were insufficiently trained and were unfamiliar with this type of aircraft.

As a solution, it was recommended in the report that no more ships of this type be ordered until their value was demonstrated in action; that all planes already in existence, with their crews, be reunited into one group to form the "Squadron of Flying Ships," and that the whole unit be placed under the command of a single officer familiar with aviation and in particular with the large planes. Finally, Mr. Shidlovsky,

who was himself a retired officer, asked that he be returned to active service and for a limited time be given the post of "Chief of the Squadron of Flying Ships." In this way he hoped to prove within a reasonable time the military value of the large multi-engined aeroplane.

The Secretary of War made a report on this subject to the Emperor Nicholas II, who was favourably impressed and approved the project. The "Squadron of the Flying Ships" was created. The Emperor recalled Mr. Shidlovsky, who was at that time about sixty years old, back into active duty, gave him the rank of Major-General and appointed him Chief of the newly created squadron. All this happened during December, 1914. Before the end of that month, General Shidlovsky, with all officers, enlisted men, planes, various equipment, automobiles and trucks, arrived at the new base near the village of Yablonna, some twenty-five miles behind the fighting lines. I went there at the same time, having been appointed to serve as technical adviser to the staff of the squadron.

January, 1915, was spent in active preparation of the ships and in orderly training of the personnel. I again did much flying, checking out the pilots and assisting in the solution of various problems connected with armament, installation of bomb racks, and special equipment on the latest type of ships. The design and construction of these planes was done in a rush, and the military equipment and armament was left to be completed at the front base. The staff of the North-Western Army, in whose area the squadron expected to start its activities, was indifferent and even sceptical,

knowing of the complete failure of the earlier ships to render any service. But General Shidlovsky and his men, including myself, were not discouraged by that as long as there were chances to prove what the ships could do.

It was again a period of work to the limit of what every man could stand. And it was a particularly difficult time for me. During January and February, I was still the only test pilot for the large planes, as well as the only flight instructor. Moreover as designer, I was responsible for any difficulty or trouble, real or imaginary, that the flying personnel might have encountered with the large, complicated and still unfamiliar equipment. For me, as well as for most of the others, it was a trying experience. But this was war. It seems almost impossible that such a quantity of work in general organization, good training, and in the solution of a multitude of other problems was accomplished in the short period of some five weeks. At the beginning of February, there were several planes ready for service and properly tested in flight with personnel checked out, equipment and bomb racks installed.

On February 15, 1915, one of the ships under the command of Captain Gorskoff, made the first successful flight over enemy territory, dropping 600 pounds of bombs. The flight was acknowledged by the adversary and during the same day a German plane came and let go some bombs. From that time on German ships visited our airport quite frequently, dropping bombs and arrows, sometimes not without results.

Late in February, 1915, I had my first narrow escape during one of the raids over our field. I was

busy in one of the hangars when the familiar signal informed us of the coming air attack. I stepped out and saw five German planes flying towards the field at a high altitude. At that time we had no bomb shelters, and expecting the bombs to be aimed at the hangars, I started towards the middle of the airport. While walking, I was glancing from time to time at the attacking planes, and particularly at one of the ships which appeared to be moving so that it would soon pass exactly over my head. Close to this ship, apparently slightly behind it, I could barely see a small black point. The meaning of this point needed no explanation, and I watched it closely because it was obvious that it would strike not in the hangar but far in the field. The point appeared nearly motionless in the sky, but was gradually growing in size. I quickly made a few steps sideways, but when I glanced up I again had the same impression that the bomb would strike at exactly the spot where I stood, and I could not decide in what direction to run. Yet the bomb was so close I could already hear the hissing. General Shidlovsky happened to be on the field not far from where I stood at the moment. I said to him, "You had better lie down on the ground."

He quickly but calmly replied, "Do you think it is best?"

I shouted, "Yes, by all means!"

He lay down, while I was already on the ground. A fraction of a second later the missile struck the ground, between the two of us. Clouds of black soil were thrown up by the explosion. It was so close that I could reach the hole without even getting on my feet. It was about three feet wide and some one and

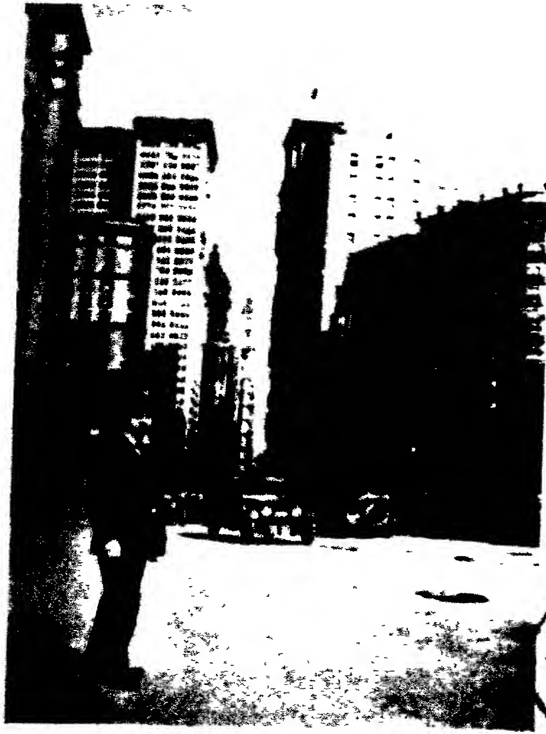
a half feet deep, apparently created by a small fragment bomb. I put my hand down in the still warm earth at the bottom, and found several pieces of the bomb which I took away as souvenirs. Most of the fragments, however, went directly or obliquely up, and if I had been standing, instead of lying on the ground, that would probably have been the end of the story of the Winged-S.

The first air raid by one of our planes was followed by others. Many successful bombings, as well as flights for observation far behind the lines were completed before the summer. The attitude of the commanding personnel of the armies became totally different.

The Staff of the First Army had telegraphed the following to the Field Inspector-General of Aviation:

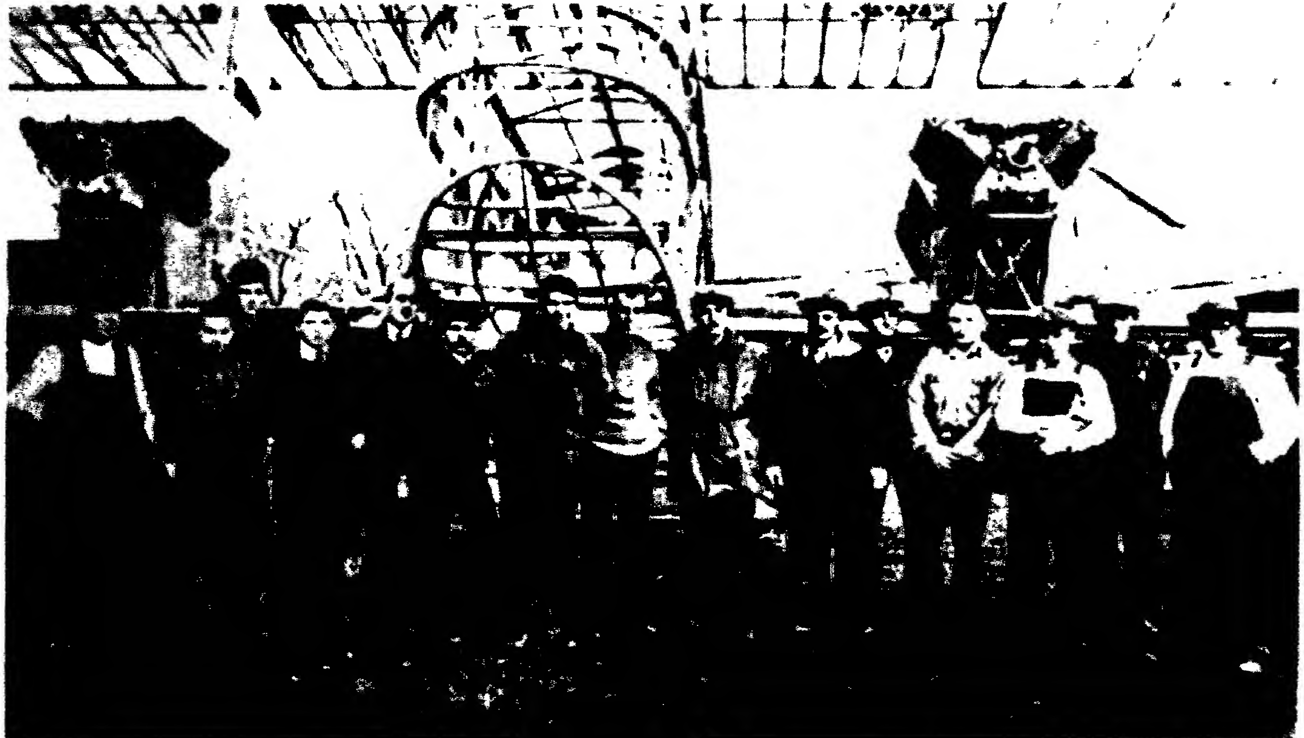
(Approximate date, March, 1915.)

"According to the Staff orders, the aircraft 'Ilia Mourometz Kievsky' completed six battle flights, during which she was given reconnaissance problems, and orders for the destruction of enemy railway terminals. The reconnaissance flights rendered very valuable information due to convenience of observation and the possibility of taking photographs of the enemy positions. According to the Intelligence Service conducted later, the bombing of the enemy railway terminals was very successful. Experience of the first series of flights showed that such type of aeroplane may give very promising results for reconnaissance as well as for bombing operations. The flights were conducted at an altitude of 3,200 metres and lasted up to four and a half hours. We may state that this type of



An immigrant.

The fuselage of S-29A being assembled in a barn



The S-29A and the personnel of the company in the Summer of 1923

aircraft, due to its tactical qualities, deserves every encouragement in development. And its future usefulness in military operations will depend on an adequate supply of well trained men in each squadron."

From that time on the large ships were demanded from all parts of the Front. The factory was ordered to produce the greatest possible number of them. General Shidlovsky was instructed to expand the squadron as quickly and as much as possible. As for myself, there was more concentrated work, together with heavy responsibility. I spent most of my time at the Front at the main base of the squadron. I gave no more flight instructions, but until the middle of 1916 I had to do all test flying of new planes that were sent from the plant, as well as test any of the ships in service that appeared unsatisfactory to the crew. Besides this, it was my duty to render engineering assistance in the solution of many urgent problems that were created by actual military experience. While the question of armament, military equipment and similar items was now taken care of by the engineering personnel of the squadron, there was enough work and worry left for me in combining their needs with the aerodynamics and structure of the planes.

Towards the middle of the summer of 1915, a considerable number of men had acquired experience in the military operation of the ships. Several encounters in the air took place. Some enemy pursuit planes were destroyed, but not a single one of our planes failed to return. However, there were men killed and wounded by enemy fire on board our ships. On June 6, 1915, one plane was severely damaged, with

two engines on one side stopped by bullets of the pursuit planes and the captain of the ship was injured. This occurred over German territory about forty miles behind the lines. The crew fought off the pursuit planes, apparently destroyed one of them, and succeeded in bringing back our plane across the Russian line, with only two motors on one side going.

Conditions were strange for engineering work. Often I participated in conferences and discussed details of encounters in the air with the men who had actually participated in the flight only a few hours before. First-hand information, as well as the convincing stories told by the bullet holes in the cabin and tanks of a ship, forced quick engineering decision and action in such cases. These efforts resulted in improvement of the planes, better methods for the prevention of fire on board, and better machine-gun protection. As time went on, several important military results were achieved.

Many valuable observation flights far into the enemy territory were successfully completed. In more important cases, an officer from the staff was on board, and when conditions for observation were good, the big planes working with maps and photography, brought back more complete and reliable information than could be obtained from a small open plane of that time. With a large crew and powerful armament, they could penetrate farther when some military mission made this desirable.

Significant results were also obtained in bombing raids. The character of warfare on the Eastern Front, with considerable shifting of troops, and a limited

number of roads, made particularly important the attacks on railway stations and bridges. Heavy damage was inflicted many times. Twice the large ships succeeded in blowing up munitions trains. One of these successful bombing attacks took place at the Prjevorsk station in Austria on June 5, 1915. The flying ship, under the command of Captain I. Baschko, located a munitions train about which the Third Army had secret information and, throwing a series of bombs, made a hit that started a huge explosion and fire. It was established later that about 30,000 shells were destroyed, together with the train. The station buildings were badly damaged.

Useful military flights similar to this one became more frequent resulting in much greater attention being paid by the adversary to our ships. Strong anti-aircraft defence was concentrated at places where "visits" of the big planes could be expected. More and more efforts were made by squadrons of German pursuit planes to bring down a "Mourometz."

Urgent and intensive work at the base was constantly increasing the ability of these ships to resist and to protect them against the new and more powerful means of attack that were introduced by the enemy. When explosive bullets appeared on German pursuit planes, the staff of the squadron became disturbed. Upon urgent request, samples of German and Austrian aircraft machine-guns and ammunition were sent to the base of the squadron and a special commission undertook a practical investigation. We took some twenty discarded petrol tanks and started shooting with German explosive bullets one tank after another, studying the various results. At first they were alarm-

ing. A few bullets were usually sufficient to produce a petrol fire in nearly every case. As the study continued, however, methods were devised which eliminated the fire hazard, even though a considerable number of explosive bullets struck the petrol tank.

It may be added that not one single "Mourometz" was ignited in the air after these precautions were introduced, in spite of the fact that time and time again fuel tanks were pierced with explosive bullets.

My personal work placed me in a different position from the majority, or even from all, of the designers of war planes of that time. They usually worked in their factory offices away from the Front and had no direct contact with the flying personnel. They learned of the success or failure of their machines from official reports. But I lived with the Squadron of Flying Ships and was well acquainted with nearly every man in the crews. Several were my personal friends. This gave me a particularly strong feeling of responsibility for my part of the work.

A great many heroic episodes took place during the flights of the large ships. On April 13, 1916, the "Mourometz X" was ordered to drop bombs on a railway station at Dandsevas. It was an important strategic point behind the German lines, well protected by anti-aircraft batteries. The plane arrived above the station and dropped the bombs from an altitude of 8,000 feet, making some direct hits. The ship was under violent artillery fire during the attack, and while the last bombs were let go, several well-aimed shrapnels exploded near by, covering it with a mass of bullets. The Commander of the ship, Lieutenant Konstenchik, was

gravely wounded in the chest, and almost immediately lost consciousness, falling from his seat with his feet still on the pedals. Other bullets pierced the radiators of engines numbers 1, 2 and 3, and damaged two engine mountings, several wires, the right wing spar and many other parts. Altogether the plane was hit by about seventy bullets. When the pilot lost consciousness, the plane first stalled and then went into a nose dive. The co-pilot was at that time in the rear compartment releasing bombs. He scrambled quickly to the pilot's cabin, but was unable, alone, to remove the unconscious commander. He pushed him aside, took over the controls, and placing his feet over the feet of the injured pilot, succeeded in straightening out the ship. A little later two other members of the crew came to his assistance and carried the still unconscious commander to the main cabin. The badly damaged plane succeeded in staying in the air and flew back some fifty-five miles, gradually losing all three of the motors with damaged radiators. They finally reached a Russian flying field. The co-pilot made an excellent landing, but the right wing cellule was so badly torn by shrapnel bullets that it dropped from lack of the supporting air pressure as soon as the speed of the plane was sufficiently reduced while rolling on the ground. In this case the ship continued to fly for more than three quarters of an hour with the right wing entirely unsupported for inverted flight conditions. This was the only case where serious damage was done by anti-aircraft artillery. While the unprecedented drama of war went on, the Squadron of Flying Ships continued to do its duty.

The following lines, taken from an official report

of the Staff of the Seventh Army, illustrate the work of the "Ilia Mourometz" planes.

"THE ORDER OF MILITARY AWARD

"THE SEVENTH ARMY. *October* 6, 1916.

"The Order of St. George, Fourth Grade, is hereby awarded to:

"The leader of the First Battle Detachment of the Squadron of Flying Ships, Commander of the Aircraft 'Ilia Mourometz II,' Military Pilot Captain Alexey Pankratieff, for his valour displayed during the battle flights conducted on the 4th, 5th, 6th, 25th, and 26th of May, 1916.

"While performing reconnaissance flights in the region between Yazlovetz and Bugatch, he personally piloted the ship and, facing danger to his life from incessant enemy battery fire, obtained accurate information about the strength and location of the enemy gun batteries and the bridges spanning the Strypa River. During the battle of May 26, 1916, in the sector Yazlovetz-Russiloff he discovered the absence of enemy reserves, a fact which was utilized by our forces during further development of military operations.

"He inflicted heavy losses to the enemy troops and transports by bombs, arrows and machine-gun fire; by direct hits at Yazlovetz which caused several fires and aided our troops in capturing the town. He later destroyed the railway track west of Bugatch railway station, making its evacuation by the enemy forces more difficult. By accurate machine-gun fire he silenced the enemy's anti-aircraft battery which was firing at the ship, and brought down an enemy plane

which tried to prevent its operation. By accurate marksmanship he silenced an anti-aircraft battery near Bugatch railway station. During the reconnaissance flights he photographed the enemy positions; the photographs being used by our troops during the battle at Yazlovetz.

"The actions of Staff-Captain Pankratieff as described herein contributed substantially to the success of our military operations."

The successful military raids of our ships resulted in concentration by the adversary of pursuit squadrons with fast, efficient planes. Obviously they had several good pilots, well informed about the unprotected blind spots in our planes. The pursuits approached our ships directly from the rear, opening fire from a short distance. A simple signal system was quickly developed, and in such cases the "Mourometz" would make a sharp turn and open fire from the side guns. This, however, would spoil the chances of bombing, and still left the plane in danger if several pursuits should attack it at the same time.

Finally, the officers of the squadron worked out a scheme for mounting a machine-gun at the rear of the fuselage, and I was given the problem of designing it. I increased the stabilizer so as to take care of the weight of a man with a machine-gun and ammunition. The middle rudder was removed and was replaced by two large rudders located far from the centre line. At the end of the fuselage a cockpit was arranged for the gunner, with a sort of a windshield as protection from the stream of air. The picture shows a man in this gunner's cockpit, and the fork that supported the gun.

The following picture shows a similar installation on another "Mourometz" plane with the gun in place.

It was difficult to provide means of reaching the rear gunner's nest in flight, because inside the fuselage were wire crosses which made the passage slow and inconvenient. A device was invented which the flying crews called the "trolley car." It consisted of a pair of light rails running along the whole fuselage from the cabin to the rear gunner's nest and of a low couch mounted on rollers. When necessary, a man could lie down on the couch and move easily below the wire crosses of the fuselage. While this installation was being completed, an unfortunate event, which could well be expected in the war, took place. On September 25th, one of our ships was attacked in the air by German pursuit planes. After a gallant fight, the "Ilia Mourometz XVI" was forced down, crashed and burned. Every man on board lost his life.

In accordance with a noble custom which was nearly always followed by the German and Russian fliers, a few days later a German plane dropped a note at the airport advising of this event. The note stated that the four men of the crew were buried with military honours. It indicated the location of their tomb, on which the Germans had placed a cross of Russian Orthodox style, with a tablet stating that it was the tomb of four Russian fliers who died as heroes in the aerial battle of September 25, 1916.

During the fall of 1916, two new types of planes were finished and placed in service. They were "Ilia Mourometz G" and "Ilia Mourometz E." The first one was in general similar to the former planes, but

had a total of 740 h.p. instead of the 640 of the previous ships. The second type, the "Ilia Mourometz E," was the largest plane produced. It had four Renault motors totalling 880 h.p. The plane had a wing area of 2,050 square feet; the gross weight was 17,600 pounds, of which 6,600 pounds represented the useful load.

Both new types of "Ilia Mourometz" had rear machine-gunners' nests. This installation proved to be extremely valuable and workable. The most dangerous attacks from behind could now be met with fire from the rear machine-gun. After that time not one single "Ilia Mourometz" was brought down while more than two hundred bombing raids were made. It is reliably estimated that at least nine pursuit planes were destroyed by the fire from our ships during the battles in the air.

On April 25, 1917, the ship "Ilia Mourometz XV," under the command of Captain Klembovsky, while returning from a bombing raid, was attacked by a group of three pursuit planes. The ship opened fire from its four machine-guns. Soon afterwards one of the pursuits was hit, fell and crashed in the woods. A few minutes later a second pursuit plane was hit and dropped down. After that the attack was discontinued and the third pursuit plane turned away. The ship was slightly damaged by bullets and one man of the crew was wounded.

During April, 1917, another ship, the "Ilia Mourometz IX," under the command of Colonel Nijevsky, was returning from a successful bombing raid. The ship crossed the Russian lines and, feeling that there was no more danger, the officer who was operating the

rear machine-gun, left his place and returned to the main cabin. A few minutes later, however, the ship was attacked by two pursuits which had approached it from behind without being noticed and had opened fire from short range. One man in the cabin was killed and another wounded in the leg. In spite of his injury, he succeeded in getting to the "trolley car," quickly moved himself along the fuselage and reached the rear gunner's nest. He opened fire and almost immediately hit one of the pursuit planes, which fell down on Russian territory. The other fighter turned away. The radiators of the two centre motors were pierced by bullets, and the plane covered the last thirty-five miles on two outboard motors.

A large number of other successful air raids were made. The gallant fliers of the "Ilia Mourometz" ships time and time again rendered valuable services to the struggling Russian armies.

The scale of the war activities was limited by the number of ships in service, which in turn depended on the training of personnel and still more on the number of planes that could be delivered. The factory could increase production, but it was impossible to get enough motors from abroad. This of course restricted the production of planes. The difficulty of getting motors made it necessary to use any type of engine of adequate power which could be obtained, and therefore, the ships had eleven different makes of engines which, of course, added one more serious difficulty to the many already existing.

Late in 1916, the first four engines designed and built by a newly organized division of the Russian

Baltic Company were delivered and installed on a plane. They performed excellently, and a large production was planned for 1917.

Altogether, about seventy-five four-engined ships were built and delivered to the Front. About one half of this number actually participated in air raids, while the rest were used for training purposes. A total of about four hundred raids were made with only one plane lost. Important military results were achieved that far more than justified the use of the modest number of men and expenses connected with the creation and activity of the squadron.

Many heroic acts and an immense amount of effort and hard work lay behind these achievements. A large expansion and much more serious results could have been expected during and after 1917. But in the spring of 1917 came the Revolution which put an abrupt end to this work.

I will not attempt to describe here this great event, which is mostly unknown and misunderstood and which was far more tragic and disastrous than even the World War that had helped it to break loose. The peaceful resignation of the Czar Nicholas II prevented at that time practically all bloodshed. Not much fighting occurred until the middle of the summer, but the progress of the Revolution could be clearly seen. There was plenty of parading with red flags, the streets became disorderly and dirty, swarms of deserters from the Front were pouring into the large cities. Many of the people were still enthusiastic about the "Great Bloodless Revolution" as it was called at that time with delight and pride. Later the same words were repeated with bitter irony. I felt very differently about

it, and gradually became convinced of the tragic hopelessness of the situation.

A profound demoralization was spreading like an epidemic of some new type of insanity. Large masses of the population, mainly soldiers and working men, became victims of the vicious but clever propaganda of radicals who promised a new era of prosperity, peace and freedom within a year, provided they could get into power. A bitter disappointment was in store for the unfortunate Russian people, but at that time many, and possibly the majority, still believed in the golden era to come within a year or two.

Early in 1918 I was again in Petrograd, having by that time made up my mind. What were called the ideals and principles of the Marxist revolution were not acceptable to me, and I was making arrangements to leave Russia for an indefinite period. I got a passport, visas and some letters of introduction, and late in February left Petrograd by rail for Mourmansk, and from there in March boarded a steamer for England.

My substantial personal fortune, earned by nine years of intensive and successful work, was invested in real estate and in government bonds. It was all lost and I had only a few hundred English pounds with me when I left my country.

Meanwhile the Revolution progressed. Lieutenant Lavrov, my personal friend and co-pilot during the flight to Kiev, was killed with the other four members of the crew in an accident which had been arranged by radical sabotage. General Shidlovsky, whose vision and administrative ability were so needed in Russia, was shot by the Reds in Petrograd, together with his son, at the end of 1918.

The Squadron of Flying Ships gradually disintegrated. Many officers were shot, among them Colonel Gorshkoff, under whose command a "Mourometz" plane made the first military flight over German territory on February 15, 1915.

Some of these events had already taken place before my departure; others were so clearly ahead that one did not need to be a prophet to foresee them. The Revolution to me was, and still is, a foolish and inglorious event. No matter what the final outcome may be, the Great War and particularly the Russian Revolution were both failures of modern humanity, and the amount of material destruction and moral harm, will remain far in excess of whatever can truthfully be claimed as their accomplishments. I felt the immensity of the tragedy and realized that my individual loss was insignificant compared to it. Therefore, I was, somehow, not much concerned about myself.

For the immediate future I was planning to go to Paris, which at that time was the centre of the military activities of the allied powers, and offer my services as an aircraft designer. As for the more remote future, it was dim. With many sad thoughts, I watched one morning early in March, 1918, the shores of Russia, near Mourmansk, disappear gradually in the haze. I was on board a small British steamer, the *Oporto*, sailing towards some unknown fate.

XIV

A NEW START IN LIFE

THERE was a week of uncomfortable travel in the hold of the *Oporto*, because the first and second-class cabins were reserved for women and children. We arrived in Newcastle, and from there I proceeded to London, and a few days later to Paris. It was at first strange and comforting to see law and order, clean streets, normally operated trains, trolley cars, shops, and running water. What a contrast all this was to the lawlessness, disorder, dirty streets, dirty cars, dirty acts of the Revolution.

As for London and Paris, I liked them both in the spring and summer of 1918, almost more than at any other time. There was something solemn and heroic in the orderly sight of the two great capitals at the critical moment of the immense conflict. Life was reasonable. Streets were clean. Only during the night, with the complete darkness and no lights, did the cities have a strange aspect.

Soon after arriving, I visited the office of the Chief of the Technical Section of the Air Service, who received me very cordially and quickly got down to business.

"The Germans are dropping 300 kilo (660 pound) bombs on Paris. So we in the Air Service had developed 1,000 kilo (2,200 pound) bombs."

He handed me a secret blueprint of the big bomb and when I had studied it, said:

"Now we want you to design an aeroplane that will carry it."

"I will be glad to do it as soon as possible," I replied.

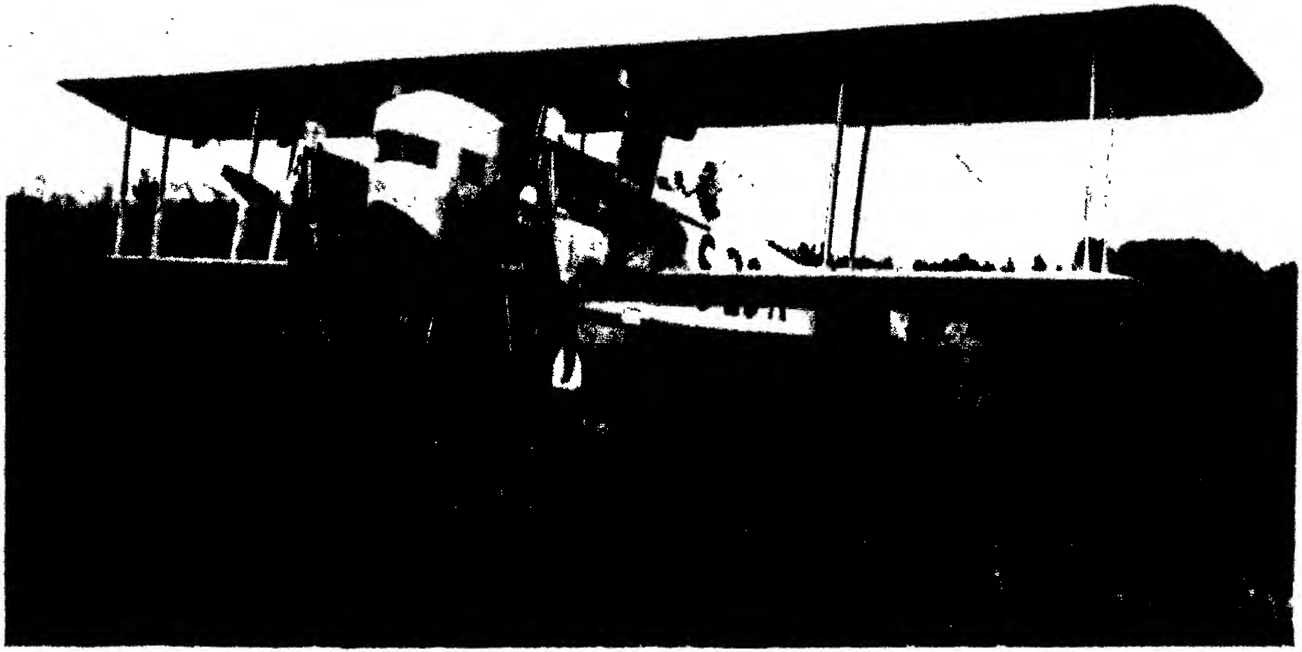
After receiving instructions, specifications, and a pass to the flying fields, I returned to the hotel and started working. Eventually an agreement was signed with one of the aircraft concerns in Paris which expected to build bombers of my design. During the summer the design was completed. It was interesting work. Sometimes one and even two days a week were spent in visiting the airports, and frequently a place called the "cemetery of enemy aircraft." This was situated not far from Paris and was used for the storage of German planes captured or shot down by the French. Some of the planes were being fixed and, when possible, rebuilt for flight testing, while the vast majority, damaged beyond repair, were simply dropped on this field. With permission, it was possible to visit the place, to tear off the fabric, and to study the planes. It was a strange sight—this large field with many hundreds of "dead" planes lying around.

Often, during clear nights, there were air raids by German planes over Paris. Usually not many bombs were dropped, but the few that fell produced a substantial impression. I saw nineteen or twenty raids in which the German planes succeeded in crossing the line of anti-aircraft defence, as well as the invisible net of steel cables raised on balloons all round the city. This protection was useful, because as a rule only a few planes were able to cross and drop bombs inside the

city, while others circled round the much less densely populated suburbs.

One interesting air raid, which I witnessed, took place during a beautiful summer night. I had gone to the racing track to see a bicycle race. A short time before one of the best known French long distance bicycle racers, Darragon, had been killed in an accident while riding behind a motor-cycle. He was very popular in Paris, and I remember well seeing him several times, years before, rushing at terrific speed behind a huge motor-cycle on one of those long distance races in which not only physical endurance is necessary for success, but also ability, strategy, and excellent team work between the bicycle rider and his leader on the motor-cycle. It might seem unusual that the death of a man known to all the youth of Paris should have produced such a deep feeling in the midst of a critical moment of a great war. It did, however, create this impression, and on that night the Vélodrome D'hiver was filled to capacity.

All receipts were to be donated for a monument in memory of the racer. It was a very interesting race, with many of the heroes of the track present, as well as many who were already retired and who had returned for this particular occasion. Every seat was occupied. While the race was on the noise of the sirens warning of an air raid was heard. But the spectators, as well as the participants, were so engaged in the race that no one paid any attention to the sirens, although the huge windows trembled from the explosions of air bombs and anti-aircraft guns. The shouts of the audience went up as though nothing was happening. The whole programme was completed in spite of the continuous



The S-29A

Various planes produced by the Sikorsky Company from 1925 to 1927

The S-29A and the S-31 — The S-32

The S-33 — The S-34

The S-35 — The S-36

thundering of artillery, and the occasional explosions of the bombs.

When I came out of the Palace it was late in the night. The air raid was not yet over, and as was usual in such cases, the subway trains were stopped, and all stations and even tunnels were opened to the public. I used this occasion to go below ground and walk through the tunnel. I remember seeing a few men sitting on benches just below the river, believing this to be the safest place. It is strange that a human being may become used to such conditions, may live and work under them; and I recall with interest and often with respect, the general behaviour of the population of London and Paris, even during these trying moments.

Early in August my bomber plans were completed. The ship was designed round two Liberty motors, but later the Technical Section suggested the use of four Hispano-Suiza motors. The project was approved and shortly afterwards the Government placed an order for five ships. During the autumn the work was continued and preparations for starting construction were made, but soon the Armistice was signed and the work was discontinued.

I remained in France for a few more months, but came to the conclusion that it would be difficult to continue aviation work in France because of the curtailment of construction. Also, the reason which had brought me to that country had ceased to exist, and therefore, partly because of what I had heard of it and partly by intuition, I decided to go to the United States and try to start life again. After an immigrant visa was secured, and necessary arrangements were made,

I boarded a steamer, and on March 30, 1919, landed in New York.

The United States seemed to me the only place which offered a real opportunity in what was then a rather precarious profession. I had been inspired by the work of Edison and Ford, the realization that a man in this country, with ideas of value—and I hoped that mine were—might have a chance to succeed. There was hope of a great development of air travel, because of the vast geographic space which made the country so favourable for aviation, and also there was the recognition of individual freedom and initiative, which meant so much to me. The United States seemed dynamic, forceful, moving forward, in contrast to the more static countries of Europe. I had met Elihu Root and a few other members of his party in Russia in 1917 and liked them very much. They seemed to me typical of this great democratic country.

When I first saw New York, with its skyscrapers, subways, busy streets and bright lights in the evening, I felt that it was important. In one week I was at home, in its dynamic atmosphere and feverish activity. I liked it in spite of the fact that in elegance and dignity, London and old Petrograd were, to my mind, far superior. New York was more alive.

Within a few days I made attempts to secure connections or arrangements that would permit me to resume my aviation activities. This was not easy, because my English was very poor, and I had little familiarity with the status of the aircraft industry. The general situation, too, was unfavourable. The large expansion of aviation during the last years of the war was followed by a considerable curtailment. Planes

and motors built for the war were now offered at extremely low prices. Transport aviation and air-lines were practically not in existence. I gradually became familiar with these facts, but there was nothing to do except continue to make further attempts to obtain some kind of work.

During the summer of 1919 it became possible to organize a company and to start preliminary engineering work. The organization, however, came to an end before the start of construction could be made. Late in the fall, I visited Washington and the Engineering Division of the Army Air Service at Dayton, Ohio, and was very happy to receive a temporary position—work on a preliminary project of a large three-engined bomber. The six weeks spent at McCook Field in Dayton were interesting and pleasant. I was glad to be in touch with aviation again, to do some work and learn more about American standards and requirements.

Having completed the project, I visited the head of McCook Field, Colonel T. Bane, who received me in a very friendly manner. However, the news he gave me was not encouraging. There was no chance to become permanently connected with McCook Field. The activities of the army organization were curtailed, and it was impossible to offer a permanent position to a foreigner while old employees were being discharged. Possibilities did not appear very bright with private manufacturers either, and Colonel Bane called aviation the "dying industry." Military aviation, and the industry that produced military aircraft were completing demobilization while private aviation was not yet born. A stranger having no connections and almost no

familiarity with the language was faced with a hard problem in obtaining any kind of aviation work, not to mention the design and construction of a plane. Upon my return to New York early in 1920, I made several more attempts to re-enter work in aviation, but without success.

Several months went by, and my modest "reserve capital" was gradually melting away. I had already checked out from a comfortable hotel, and had rented a small two-room apartment on West 137th Street. While I continued to try to locate an aviation job, it appeared more and more clear that very soon it would be necessary to look for any kind of work. This was a difficult problem. Since I had been nineteen years old, I had always worked in aviation and every other field was unfamiliar. By the fall of 1920, I changed my apartment for a single furnished room at six dollars a week. In order to stretch the remaining few hundred dollars, I started a budget which allowed eighty cents a day for all meals. Lunch and dinner usually consisted of a cup of coffee, rolls and a plate of Boston baked beans. While eggs and meat were excluded as being too expensive, yet with the coffee and beans nicely served in any of the multitude of modest restaurants in New York, I felt fine.

Late in the fall a friend of mine told me of an opportunity to give lessons in mathematics in a private school, The Russian Collegiate Institute, to Russian immigrants, mostly workmen of the East Side in downtown New York. I replied that I had never given any lessons except in flying, and never had intended to do so, but that I would of course be glad to try. A couple of evenings spent in going over my arithmetic, algebra

and geometry proved sufficient to recall the subjects. Lessons were then started, and went on reasonably well. Soon afterwards, having built some connections among the Russian immigrants, I began to receive invitations to deliver lectures on aviation and on astronomy. The latter science was always a subject of great interest to me. In Russia I had several books on the subject and also a small telescope. My knowledge, while extremely modest, was sufficient for my listeners, and the lectures were usually popular.

As time went on, I began to be requested to lecture to various small organizations, mostly in the suburbs of New York. They usually paid from three to ten dollars, which was not an easy way to earn a living because it took some time to prepare the lectures, provide the lantern slides, many of which were borrowed from the American Museum of Natural History, and to carry a heavy projector one or two miles from some remote subway station. However, it helped to relieve the financial pressure, and while I continued to live nearly as modestly as before, there was no longer any need to worry about the future. The work itself was rather interesting. The groups of Russian immigrants to whom I talked were mostly workmen and peasants who had come to the United States before the war. A great many of them were formerly radical in their beliefs, and had accepted the Revolution of 1917 with joy and enthusiasm. For about two years they were still devoted heart and soul to the Bolshevik cause. All news that came from the general press was discarded as being "capitalistic falsehood," and they had full confidence in the propaganda from radical sources, of which there were plenty in this country.

These, however, must be given credit for having developed to a remarkable degree of efficiency the methods of misinforming the unintelligent. This "fool's paradise" began to crack from one end to the other, and in 1920-21 large groups of Russian immigrants found themselves at the cross-roads, having by then realized that they were being deceived by the Reds. This change, which could not have been accomplished by the most powerful speakers or writers, was a result of more modest, and also more convincing, evidence. The true plight of the unfortunate people of Russia gradually became known from letters sent by relatives, and probably still more from letters and information received from former Reds among the workmen who, burning with enthusiasm and faith, had returned to the socialistic country of workmen and peasants. They wrote mostly of desperation and tragedy. Several of these men went to Russia with their belongings, instruments, a few hundred, and sometimes even a few thousand dollars—the savings of years of labour. The few who succeeded in escaping from Russia, usually carrying away nothing except insects, told a story quite different from the rosy pictures painted by the radical papers. In addition to a general disappointment among the best and more intelligent of the Russian immigrants, this disillusionment engendered a real desire for true knowledge and education.

As a result, many people from eighteen to thirty-five started to take lessons in mathematics, history, literature and other subjects. Great credit is due these men who were willing to spend two hours every evening after a day's work in order to improve their education, and who were willing to spend their money to

pay for lessons, the subjects of which were of little practical assistance in their everyday life or work. A few intellectuals organized this evening school, and obtained financial assistance from an American educational institution. The purpose of the study was mostly an attempt to gain a better understanding of this perturbed world.

While my earnings were modest they were sufficient to live on, and the character of my occupation was convenient in a very important way. I was busy only during the evenings and week-ends. Much of my time, therefore, was at my disposal and I had opportunities to work out on paper some new projects, and was able to remain in touch with aviation in general. Once in a while when visiting airports and watching planes in the air, I felt bitterly disappointed in no longer being connected with the great and wonderful flying work to which I felt I belonged. I would see somebody else flying, and think: "Perhaps I could do it better—— I know I could." Such resentment came rarely because usually my teaching gave me satisfaction and little worry. This I could appreciate keenly because of the past. Success on a large scale always requires for achievement not only hard work, but also plenty of worry.

My lectures brought me in contact with large numbers of people. The story of my former aviation work and of its future possibilities was often received with much interest. The idea of taking part in the creation and construction of a new plane of an advanced type appealed to many of my students and friends. The building of an outstanding aeroplane would represent such an achievement. I had a feeling and a conviction

that I could still make a success in aviation.

And so, during this period, I worked on the designs of commercial aeroplanes, most of which pointed towards the S-29, which I subsequently built. I thought of bigger ships, of four-engined aeroplanes, carrying forty or fifty passengers, and sketched them on paper. An excursion into the future is always interesting and essential to the inventor, the creative engineer. In this development work, he gets an idea and adapts it to general conditions. The market for his product and the instruments which guide it give it life, and science provides the materials. Forty years ago, Andre could dream of flying to the North Pole, but he did not have the instruments which were at Byrd's disposal. But the engineer who adds to the equipment of mankind dreams of the future and moulds the machines in his mind. During these trying years I was building in my imagination, and sometimes working out on paper, the aeroplanes which I have built and which have flown the oceans. That should not sound vainglorious, it is the fact; and it should be encouraging to those who are following the pioneers. There is much yet to do.

XV
BACK IN AVIATION

UP to 1922, numerous attempts proved that it would be impossible either to obtain a position with one of the existing aviation concerns, or to finance my own company by the usual methods. Time was working against me. My old bombers, the only real aircraft that I could talk about, were becoming obsolete, and the long interval of time without active work was an obvious drawback whenever I attempted to make connections or start a new enterprise. At the same time, however, my modest scientific efforts and lectures forced me back into aviation. In order to make the lectures attractive and modern, it was necessary to keep in touch with the latest developments in aircraft.

Becoming more familiar with the geography and general conditions of the United States, I was convinced that this country sooner or later would see the greatest expansion of air transportation. My lectures brought me in touch mostly with people of modest means, but with enough faith and enthusiasm to offer assistance if I should start my own aeronautical enterprise. Other men volunteered their assistance as workers, satisfied with a minimum amount of money which would permit their living, while the rest of their

salary would be subscribed to the organization. This would enable me to step back into aviation in a rather unconventional way. It was risky to start on such a basis, but it seemed the only way.

The fact that every subscriber took a chance of losing all his investment was mentioned in every printed paper and at every meeting. An attempt was made, also, to bring into the organization a large number of small subscribers, so as to protect the individual investor from heavy loss. The preferred stock was ten dollars a share, and for every two shares of preferred there was issued one share of common, of a par value of five dollars. The preferred stock called for an eventual return of eight per cent. The arrangement was a source of continuous worry to me, but I later had the satisfaction of knowing that every investor got back two dollars for every dollar he put into the venture.

And so, on March 5, 1923, the new company was incorporated under the name of the "Sikorsky Aero Engineering Corporation." The programme consisted in collecting as many subscriptions as possible and starting at the earliest moment the construction of an all-metal, twin-engined passenger transport plane.

It was an interesting period. The commencement of actual work was acclaimed enthusiastically by a few friends. Considerable doubt was expressed by others who were certain that we were beginning under hopeless conditions, and that competing with large, established concerns would be entirely impossible. The fact that the work was brought to a complete success, in spite of difficulties and adversities, was owing to the efficient, friendly and loyal support of many people. It is to this group of men that the credit for my first

aeroplane built in this country should be given. Some of them were officers of the former Russian army or navy; in many cases it was their first job since they had left home. Others were mechanics who had been working in factories in this country, but who were willing to stake their modest savings and their labour in an enterprise in which they had faith. That such faith touched me, and made me more than ever determined to build a fine aeroplane, can easily be understood. I have decided not to mention individual names; it was the whole group which made possible an achievement that at first was considered by many to be hopeless.

Early in the spring of 1923, work was started on the farm of one of my friends, Lieutenant Utgof, not far from Roosevelt Field on Long Island. The total subscriptions at that time were a few thousand dollars, with possibly less than one thousand dollars in cash actually received. But I decided that to facilitate further investment, as well as to save time, it was best to begin work. The decision proved to be right. As the construction went on, many subscribers visited the place, mostly on week-ends, bringing others to see the progress made, and often they were willing to contribute more to our funds. The purchasing of necessary machinery, and even material, had to be postponed until enough money could be collected.

Our equipment was extremely primitive. The first instrument we devised was a home-made scissors for cutting duralumin. The material for the scissors was an old automobile bumper, bought in the neighbourhood junk-yard for fifty cents. With a hand drill-press and a few other simple tools, one of our members

made scissors strong enough for sheet metal which cut practically all the metal used in our first aeroplane. That junk-yard was very useful. We got from it angle irons from discarded bed-springs, which proved very valuable. And much to my delight I found in the five and ten cent shops a lot of turnbuckles from army stores, which had originally been made for aeroplanes, and which were being sold for radio antennae. I gathered up all I could lay hands on, for otherwise they would have cost forty or fifty cents each. Their improvisations, some of which would make a modern designer shiver with apprehension, frequently required me to redesign parts of the aeroplane, displacing some members to make use of the unconventional shapes which were all we could afford. As I look back at that time, I sometimes wonder that we had the courage to go ahead with such makeshift parts, but my early experience in utilizing whatever came to hand made it seem quite natural to use bed-spring angle irons and similar materials. As a matter of fact, the aeroplane was very strong.

Towards the autumn, the S-29-A—the Sikorsky Type 29, American, for I was sufficiently grateful to my newly adopted country to put in the A—was more than fifty per cent completed. But then we ran into more trouble. Work in the open during the summer was pleasant. A hangar, however, was beyond our budget, and the smaller buildings of the farm could only house separate parts, so the whole aeroplane, when assembled, had to stand outside. When it rained, work was interrupted. When the weather became very cold, working conditions would have been impossible if it had not been for the enthusiasm of the

group, who were willing to suffer and burn their hands on cold metal, in order to finish the job. Perhaps it made us healthy, but it was not an ideal way to build an aeroplane. Also the number of visitors diminished considerably in cold weather, and the collection of money became more and more difficult.

While I, personally, had to do all kinds of work in connection with the design, complete stress analysis and supervision of construction, yet the greatest trouble and worry was finances. We had our bright days, however. One of these was when Mr. Serge Rachmaninoff, the composer and pianist, came to our assistance with a subscription which gradually grew to five thousand dollars. Also, he agreed to become the vice-president of the corporation, of which I was president at that time. His support increased the morale of the group, as well as the resources. Nevertheless subscriptions dropped, and finally only a handful of men were labouring, sometimes for weeks without receiving any salary. We did, after a time, move to a rented hangar on Roosevelt Field, and as our credit at the junk-yard was unlimited, and we bought our duralumin at small stores, we managed to keep going.

The S-29 was slowly completed, and in April, 1924, the ship was about ready to fly. This was one of the most trying periods in the life of the organization. The S-29 was, in several respects, a nice ship and well built, but a few second-hand parts had been used which were obviously unsatisfactory. The tyres on the wheels were bad, and we had blow-outs while the ship was standing still. Our engine situation was worse. We had two second-hand war-time engines which were not sufficiently powerful, and not very reliable, but we

could not afford better ones. Our financial situation was acute. For some twenty weeks none of the personnel received any salary. So self-sacrificing were they that they became a sort of legend at Roosevelt Field—the men who worked without pay. The few dollars that could be collected were spent to buy food and that was all that could be offered to men who laboured twelve to fourteen hours a day. The ship looked ready for a long time, and some of the old investors began to think that there was something inherently wrong with the aeroplane, that it would never fly. The secretary of our company said once at the end of April that we must fly, even if it were unsafe.

So, early in May, the S-29-A was ready; the engines were tested, and there was some oil available. But we could not afford a barrel of petrol. Somehow we got a few cans of it from the neighbouring filling station and put it in the tanks. Early in the morning of May 4th, the ship was wheeled out. The day before I had made a few taxi-ing tests on the ground, but I did not want to do more because I was uncertain of the quality of the tyres.

The engines were started. I wanted to take only three men, but seven or eight crowded into the aeroplane. It was a mistake. I knew it at the time, but did not have the heart to put them out, after all their efforts—a wrong frame of mind for one who is doing such difficult and dangerous work. When I opened the throttle the ship began to move from our hangar towards Mitchell Field. The take-off run was long and I was more than half-way across the field when the plane lifted. I had had no chance to measure the

actual power of the engines and attributed the unusually low revolutions to the excessive pitch of the propellers. The real reason was lack of power. The ship slowly began to gain altitude, and although I wanted to land, the borderline of the field was too close. I had to continue over Roosevelt Field and over Mitchell Field, and then, at not more than 100 feet, I turned to the left. The engines began to lose power, and the ship started to settle down while we were flying towards a golf course. A few seconds later I realized that an immediate forced landing was inevitable. I made a last effort, pulled hard on the control wheel, and just cleared the wires along the road. This, however, resulted in a further loss of speed, and the ship landed heavily on the golf course. It was not damaged by the impact, but after running for about 100 feet, it struck a ravine and partly turned over.

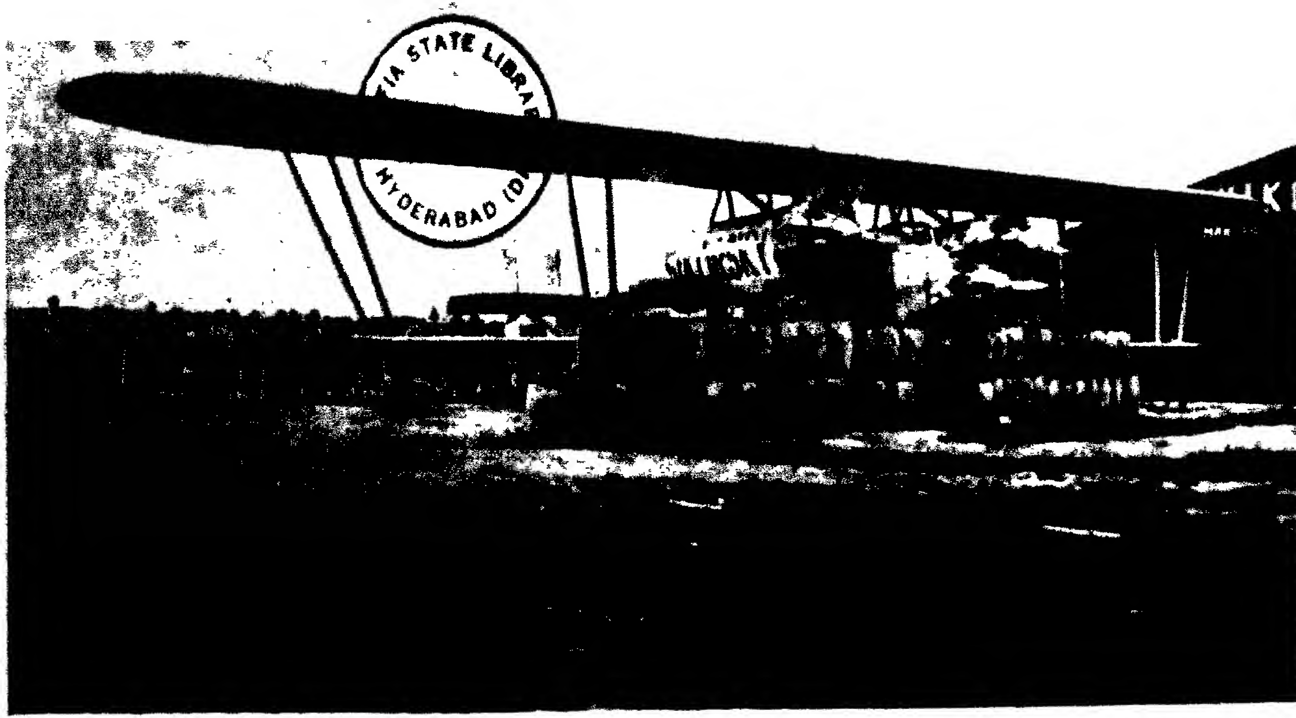
Everyone climbed out with some scratches and bruises, but no one was seriously hurt. A brief inspection showed that the plane was seriously damaged—both propellers were broken, both radiators were cracked, hot water was pouring out, and the landing gear and wheels were broken. Many other parts were smashed or bent out of shape. A crowd started to gather and after asking some of my assistants to disassemble the ship and get it back into the hangar, I took my motor-cycle and left. Our situation now looked hopeless. One of my close associates said: "This is the end."

When anything goes wrong I always have to get away by myself. I rode out to a park near Port Jefferson to think over the situation, which looked gloomy, indeed. How long I sat there I don't know, but I

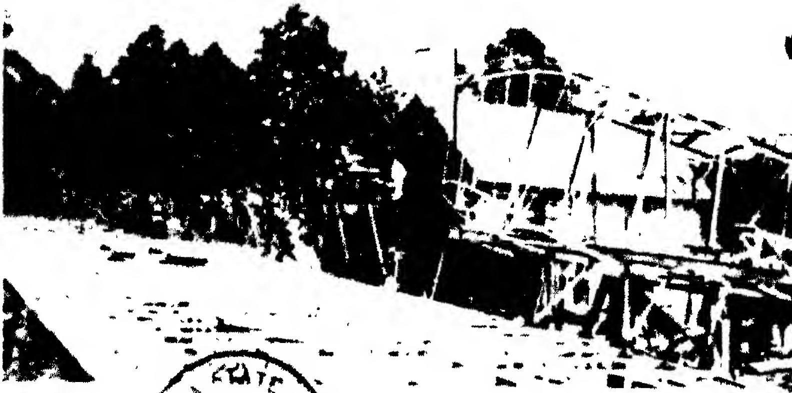
returned home late in the evening, determined to make another attempt. All our labour could not go for nothing. The first thing to do was to get the men together and arrange for the repair of the ship. Their friendly loyalty made this possible, despite the absence of money for salaries. But how to replace the major parts which had been broken was our greatest problem. We needed more powerful motors, new wheels of proper size with good tyres, new propellers, new radiators, and a few other parts. This demanded a substantial expenditure of money, and we had none.

By the middle of summer, even without money, we had done much to repair the plane. It was again standing on wheels, and the damaged parts were mostly straightened out, often at a greater expense in labour than would have been necessary to purchase a new part. During this period we had one bit of good fortune. Captain Nungesser, the French war ace, had come to Roosevelt Field to give exhibitions, and the newspapers were much interested in him, as we were ourselves. By some miracle, the telephone bill had been paid for two months in advance, and as it was the only telephone at our end of the field the newspapermen used it frequently. They paid for their calls, and at the end of the day we would grab a dollar in change, or perhaps more, and go out to buy milk and bread for our lunch or dinner. I don't suppose those reporters ever realized that they were enabling us to eat, we were much too proud to tell them the joke, but they bought us many a meal.

We still had no motors and no real hopes of getting them. With this in mind, I decided to call a special meeting of the stockholders of the company, and make



The S-35 with the fuel prepared for the long flight



The Sikorsky "Factory" in 1923, at Roosevelt, Long Island

The modern Sikorsky Factory in Bridgeport, Conn., that became the home of the organisation in 1929

a last attempt to collect the necessary money. The situation was not promising. We had many friends, most of whom had contributed as much as they could. There was another group of stockholders who became discouraged with the situation—they did not want to put any more money into the company, and were exceedingly critical. For this special meeting we sent invitations to a select group who were still friendly and loyal.

The scene stands out vividly in my mind and I am not surprised that it does for that was a crucial point in our affairs.

The office was small and into it crowded some fifty people of all sorts, most of them Russians, all of them with questioning expressions on their faces. As soon as they were seated and quiet, I arose and deliberately walked over to the door, turned the key with as loud a click as I could manage and dropped it in my pocket.

"That door will not be unlocked," I announced, "until two thousand five hundred dollars is subscribed."

That seemed an enormous sum at that time and I could see some rather anxious looks in the audience.

"You need not worry," I began. "The ship is efficient. It takes off with very low power, and given good engines we are certain of success."

I had made arrangements to buy two overhauled Liberty motors at a reduced cost. And I told them that if the money were not forthcoming everything we had put into it, money, time and hope, would be lost. My appeal was not in vain. They subscribed two thousand dollars, and as I continued to talk, the whole sum gradually was made available.

Hopeful and happy, it was with the realization of

one more load of heavy responsibility to this fine, trusting group of men—and aviation pioneering required trust in those days—that I left with the hope of making one last effort. Most of the men who did work at that time were present, because all of them were stockholders. The fact that good engines and a few other necessary parts could now be purchased made them happy.

During the month of August we got the engines installed, and by the end of the month the ship, re-enforced, and changed in several places, was again ready for tests. When we tried the motors we could feel that the ship would fly well with the greater power. To test the controls and the landing gear I did some taxi-ing along the ground, and finally decided to make another flight.

In the afternoon of September 25th, we wheeled the ship from the hangar. The nervous and abnormal frame of mind which had prevailed with all of us during the first flight was no longer present. I knew the ship would fly this time, but I decided to take no more than three men with me. It was difficult to refuse the others, but it had to be done. After a long test of the engines, we entered the plane. I took the controls and pushed the throttle ahead. The S-29 started to run along Roosevelt Field much more easily; the increased power was obviously there. After a short run, the ship took off. I soon realized it was tail heavy, but not enough to get me into trouble. I permitted the plane to climb to 1,000 feet, made one long circle over the surrounding area, and returned to Roosevelt Field. After a nice flight of about ten minutes, a good landing was made, and the S-29 with a crew of four happy men

taxied back to the hangar, where it was enthusiastically greeted.

At last, despite all our worries and misfortunes, we had built a good aeroplane. The first flight was followed by others. Minor refinements were made on the ship and soon it was possible to carry passengers and make demonstration flights. The ship was probably the first, or, at least, one of the very first, twin-engined aeroplanes built in the United States capable of flying on one motor. It had a large passenger cabin which would hold fourteen persons; a maximum speed of 115 miles an hour, and it could cruise easily at 100 miles an hour. It had good take-off and landing characteristics, and in spite of the difficulties experienced during its construction, it proved to be a very strong machine.

I was happy to resume flying. It gave me a feeling of having come back into the field of activity to which I belonged.

XVI
FLIGHTS OF THE S-29

OUR first opportunity to earn money with our new aeroplane was rather amusing. We were offered five hundred dollars to transport two grand pianos from Roosevelt Field to Washington, D.C. The money appeared a considerable sum to us and was a great help to our modest budget. Also that our aeroplane could carry grand pianos showed that it could carry loads. The flight was accomplished without difficulty and we hope that it brought desirable publicity to the organization that hired our ship. It certainly brought us favourable publicity. That was the beginning of a number of flights during the autumn and early winter of 1924, which were helpful to our small organization. It became possible to interest a few more subscribers, and to base our future activities on some successful accomplishment.

Once I was approached on the flying field by a man who wanted to charter the ship to bring about 2,000 pounds of useful load—the words are used advisedly—from some place in New England to Roosevelt Field. I found out that the load represented a certain number of cases of whisky. It was promised that automobiles would wait at the edge of the field on the speedway, and would immediately take care of the shipment. In spite of the substantial amount of money involved, I

politely declined the proposition, saying that we were not in that kind of business. My prospective customer was very much disturbed and threatened to come to the next stockholders' meeting and tell them that the president of the company had declined to accept a profitable business proposition. Several other unobjectionable chartered trips were made, however, and helped our finances.

The successful flights of the S-29 proved the practicability of twin-engined commercial transports and the safety that could be obtained from such ships if they could fly on one engine. It was this particular characteristic which probably helped us to earn the interest and confidence of some of our New England friends who later became stockholders and who were responsible for the further development of the company.

During the few years of its existence the S-29 made a considerable number of flights. I piloted the good old ship myself during more than two hundred. It was an interesting plane in many respects, and can well be considered the forerunner of the twin-engined air-liner of to-day. Many persons who had never been in the air took their first ride in the S-29 and in many cases they became enthusiastic about flying. At that time aviation revolved round small planes doing stunt flying in aerial circuses, and carrying a few passengers on short hops. It was the era of barnstorming, which did much to keep private aviation alive, but it was not a business-like method of transportation. In this respect the S-29, with its roomy cabin and row of seats, impressed many people who have since become friends of air travel. It carried several thousand passengers during its life-time,

and we had many interesting experiences in it.

On the three hundred and third flight of the S-29, on December 18, 1925, I took off from Miller Field on Staten Island, for Westbury, Long Island. It was late when we left, and it became entirely dark while we were still in the air. The ship carried no equipment for night flying. The crew on the landing field misunderstood instructions, and had no lights ready. My experience in night flying was meagre, and I became lost in the air beyond Westbury, and flew much farther over Long Island. As the night grew darker I realized it was necessary to land. I could barely distinguish the wooded sections from the open fields, but I throttled the engines and started to glide down. A few moments before landing I heard a strange noise, and felt that the ship had hit something. Nevertheless it continued to glide smoothly, and made a fair landing. As it came to a stop, we stepped out of the plane and discovered that a wing had broken the tops from several strong trees. The wing, however, remained almost intact, although several ribs were bent, as well as the leading edge cover. Later on, I found a broken limb from one of the trees and am keeping it as a souvenir of this flight, which was one of my narrow escapes.

The next day in walking along the field on which we had landed, we found it rather short for a normal take-off, but I decided that if we removed everything possible from the ship and took petrol for only one half-hour, we could get off the ground and clear the trees. I inspected and measured the field, and placed a flag at a spot far enough from the end of the field to permit the ship to stop if it could not take off. I decided to cut off the engines immediately at that point if the

plane were not in the air. We moved the S-29 all the way to the other end of the field, until the tail was in an adjacent vegetable garden. The wheels were blocked, the engines started up and I let them run for a few minutes to make sure I had every bit of power available, because the end of the field and large groups of trees at the edge looked uncomfortably near. Finally, I ordered the plane to be pushed ahead. With no load, it took off easily and a few seconds later I was pleased to see the trees already below and not straight ahead. We returned to Westbury without even repairing the damaged parts, having merely pasted a piece of fabric where it was torn off.

In 1926 the S-29 was sold to Captain Roscoe Turner. Under his capable control the ship made a number of flights across the United States. He carried a large number of passengers, chartered flights for various concerns, and finally had the ship arranged as a flying cigar store. The S-29 stood up and proved to be a fine, reliable ship under hard service, rough landings, bad weather and continuous work. Its life ended in a rather romantic way. It was purchased by a moving picture concern and disguised as a German bomber. In order to film the picture of the fall of a military bomber, the ship was loaded with inflammable materials, and when it reached a sufficient altitude the crew jumped with parachutes after setting fire to the ship. The faithful old ship which, after May 4, 1924, had not had a single crash in its long career, came down, crashed, and was destroyed by flames.

While the S-29 was still flying, several other small planes were designed and built. In 1925 and 1926, there were a large number of JN-4 training planes—

called Jennies—and some other types left over from the war period. They were used by pilots for private flying and barnstorming. We developed a new wing of improved characteristics, the G-S-1, the initials standing for Gluhareff-Sikorsky—Mr. Gluhareff being responsible for the development of this airfoil. With this wing mounted on a Jenny fuselage, the planes were safer and faster and had greater lifting capacity. About twenty of these wings were made, and in 1937 one of them flew to the National Air Races at Cleveland, still giving good service. We also built, in 1925, a two-seater observation plane for a foreign country, which took second prize in an efficiency contest. Another plane was a five-seater, mounted on floats, which was used by an oil company in South America. Another was a small single-seater, powered with a 60 h.p. radial engine.

It was after producing these ships that we took a step that proved unsuccessful at first, but which was later to have a tremendous effect in determining our development of aeroplanes. It was the S-34, a twin-engine amphibian. It did not turn out to be practical, but it furnished valuable experience and information in a new and difficult type of multi-engined amphibians. During a test flight, with the late Captain Collier at the controls and myself as observer, the plane developed engine trouble while flying low over the water. A forced landing down-wind resulted in a crash. We climbed on top of the damaged and slowly sinking ship until a motor-boat arrived and took us ashore. But that plane taught us much which was later useful.

Despite our modest successes, which had won us respect and friends, this was a difficult time. The

organization was not important enough to obtain Government orders, and the private market was limited and unreliable. Most of the sales represented new development work, the cost of which could not be covered by the price of one plane. And there were some keen disappointments; the worst being our next ambitious effort.

XVII

THE S-35

FROM the beginning of 1924 until the latter part of 1926 our factory was located in one of the two old wooden hangars on a corner of Roosevelt Field near Westbury, Long Island. There was no door on the hangar and the temperature was exactly the same as outside. This was anything but comfortable in the cold months, but somehow the work progressed. Behind the hangar were two sheds about twenty feet by sixty feet. With a couple of iron stoves, it was possible to maintain there a temperature somewhat above the outside. Not very much so, because of numerous holes and splits which permitted the wind, rain and snow to enter quite freely into what we called the main shop. At the end of it was a partition that made a draughting room and a smaller one which served as my office. The roof leaked in hundreds of places. It was like solving a crossword puzzle for the engineering personnel to leave their drawings on the boards on a rainy day, because depending on the wind direction it would leak in different spots.

A similar problem existed for the night watchman. Only in this case there was no puzzle at all, because if it started to rain during the night he quickly found out whether or not he had been correct in choosing the right place for his bed. At that time there was

no permanent night-watchman and those duties were carried out by someone in the organization, once in a while by myself.

The equipment of the shop was extremely modest, and it was remarkable how the personnel was able to produce efficient planes under these circumstances. The equipment included, however, some structural test machines that were "home made," and were built of various parts purchased mostly in a junk-yard. While simple and crude, they supplied information that was satisfactory at that time. In this case, as well as in many others, the ability, energy and determination of the personnel compensated for the deficiency of equipment and the planes produced were in no way inferior to those built in well-established and equipped factories. The difficulties, however, were considerable.

During the construction of the S-32 in the latter part of 1925, many parts such as ribs, spars and some others, were made for a second plane. Early in 1926, after delivery of the S-32, we were able to put in time and effort on this new plane, which was designed as the next twin-engined transport to supersede the S-29. The ship was well under way in the spring of 1926 when an event took place which had serious consequences.

About that time I met the famous French military pilot, Captain Rene Fonck, one of the outstanding heroes of the Great War, who arrived in the United States to arrange a flight from New York to Paris. Captain Fonck became interested in our plane, and decided to use it. It was expected that part of the expenses of the undertaking would be covered by

advertising contracts connected with the flight. Analysing the situation several years later, I believe that it was this particular detail which indirectly contributed to the tragic outcome of this unfortunate enterprise.

At that time, however, our small organization was still struggling hard for existence. The flight seemed a good opportunity for us to make an important step forward, and it was necessary to take this chance. From an engineering standpoint it presented a difficult problem. The plane which was under construction at that time was originally designed as a medium range twin-engined passenger transport. For the trans-oceanic flight three motors were preferable and the basic requirement was a very long range. Therefore, important changes had to be decided quickly and the plans altered accordingly. A considerable amount of design engineering work and new stress analysis were hurriedly completed, and the work resumed along quite different lines. The span and area were substantially enlarged by the addition of intermediate sections of wings. The front of the fuselage was re-designed to permit the installation of the third engine. The whole centre section was reinforced to allow for the greater span and of much greater gross weight. A rather complicated, but ingenious, petrol system was produced in order to take care of the huge amount of fuel needed for the 3,600 mile flight. Those problems, as well as a number of others, were difficult, particularly because they had to be incorporated in a ship which was already partly built. Moreover, we had modest and primitive shop equipment, and not much time. However, the huge, elegant, efficient, and

modern-looking aeroplane gradually took shape in the old, leaky hangar. Several visitors openly expressed doubts that such a plane could have been constructed in the shop with our equipment.

Difficulties of various nature delayed somewhat the completion of the S-35. Meanwhile, it was necessary to release information about the proposed flight to Paris for the prize offered by Mr. Raymond Orteig. Once this was done, extensive newspaper publicity resulted, bringing the proposed flight into the limelight. While I personally was thankful for the many friendly and encouraging articles that appeared almost daily in the papers, to me it was more a source of worry and regret than of satisfaction. All would have been well had the flight been completed, but the advance publicity did not make me happy at all. Yet the circumstances were such that there was not much that I could have done about it.

In August 1926, the S-35 was finished. After the necessary tests of the engines and other mechanisms, some taxi-ing was done along the ground, and the plane was ready for test flights. Captain Fonck and myself were at the controls. Only two outboard engines were used, the centre one being started but left idling; in spite of that the plane took off very easily and performed well in every respect. During the second flight, we climbed several thousand feet high and made a flight over New York. There were practically no corrections or adjustments needed after these test flights. Much work, however, was still left to be done; the installation of additional petrol tanks, of various equipment, and of the auxiliary wheels which appeared to be needed for the take-off of the

overloaded plane. The wheels were to be released and dropped after the take-off.

During the latter part of August and early September, this work was completed. Late in August the S-35 made a flight to Washington, where it was demonstrated to Government officials, among them the late Admiral Moffett. The plane apparently created a favourable impression, particularly by its ability to climb well with full normal load on any two motors. Upon the return of the S-35 to our hangar on Roosevelt Field, the work of installing special equipment was continued in a rush, while several more performance and consumption test flights were made. The plane was loaded with 8,000 pounds, and the following results were obtained: maximum speed, 143 miles an hour; cruising speed, in excess of 120 miles an hour; climb, over 800 feet a minute; climb with one motor stopped, 250 feet a minute.

For quite a few years this performance remained unsurpassed by any plane of similar size and power. There was an abundant and generally favourable publicity given to the proposed flight. Yet for me this period, the first two weeks in September, was one of growing worry and dissatisfaction.

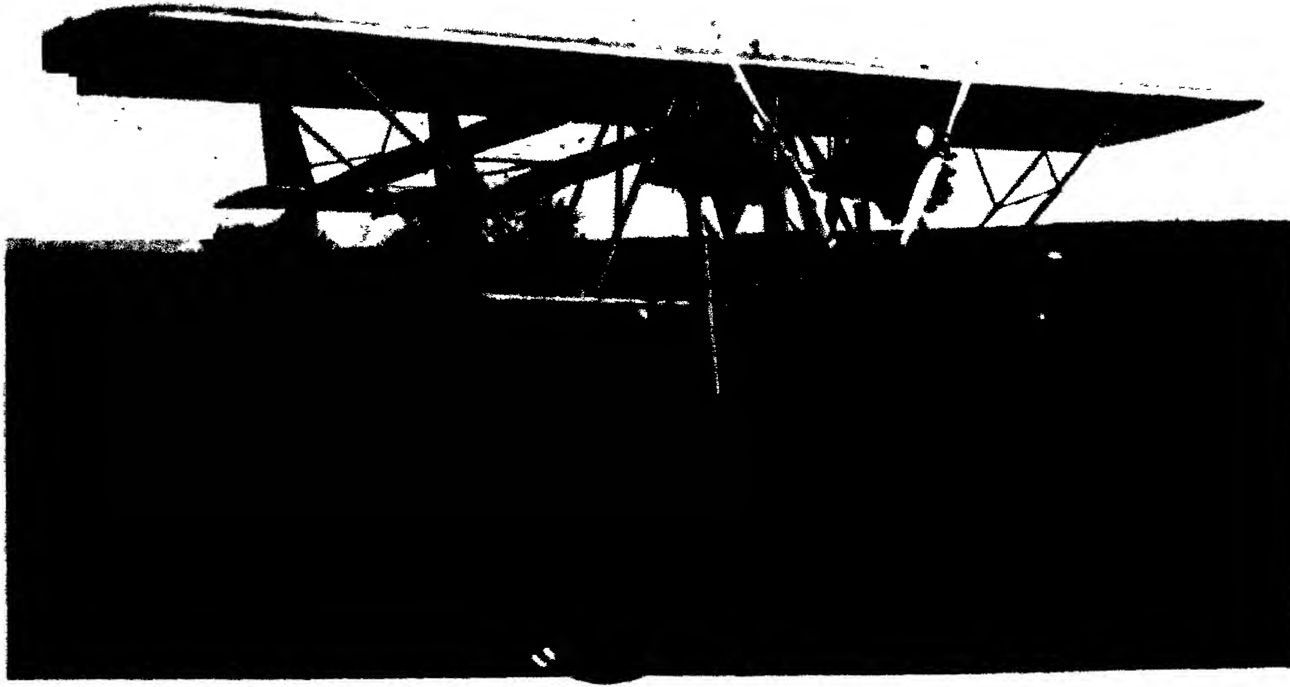
I had complete confidence at that time, and have still more at present, that the S-35 was able to make the flight. The runway at Roosevelt Field was sufficiently long for the take-off under normal conditions with the expected overload. However, I felt that the ship was under tested and that there was no possibility of properly making all the necessary tests. It was decided that the flight must be started during September, and as early as possible. The days were

already getting shorter, and there were greater chances of having bad weather somewhere along the great circle route which would take the ship far north of the latitude of New York. We needed to test the functioning of the auxiliary landing gear, and make take-off tests with gradually increased loads, the latter being the more important. The normal procedure for such a test would be to take on board ballast, preferably water, and release it after the take-off was made and the initial climb was determined. Water would be safe to release during any moment of the take-off run or immediately afterwards, even while the plane was flying over a populated area. The emergency release of any other load would have been a nuisance or even dangerous in the densely populated area around Roosevelt Field. The simplest way would have been to use the main fuel tanks for water ballast, while the engines were fed from the smaller service tanks. But this procedure was impossible; for, after filling the tanks with water, they would need to be well cleaned, and this could be done only by dismounting the tanks and disassembling some parts of the fuel system, putting the plane out of commission for a few days. This, in turn, could not be done, because it was felt that during one of these days the weather might be favourable and because of the late season it would be unwise to take a chance of missing it. The right thing to do would have been to proceed with all necessary tests, and to postpone the flight until the next spring, if by the time the tests were completed it was too late to start. But our little group, which by extreme effort had produced the fine ship, was not powerful enough to put off the flight.

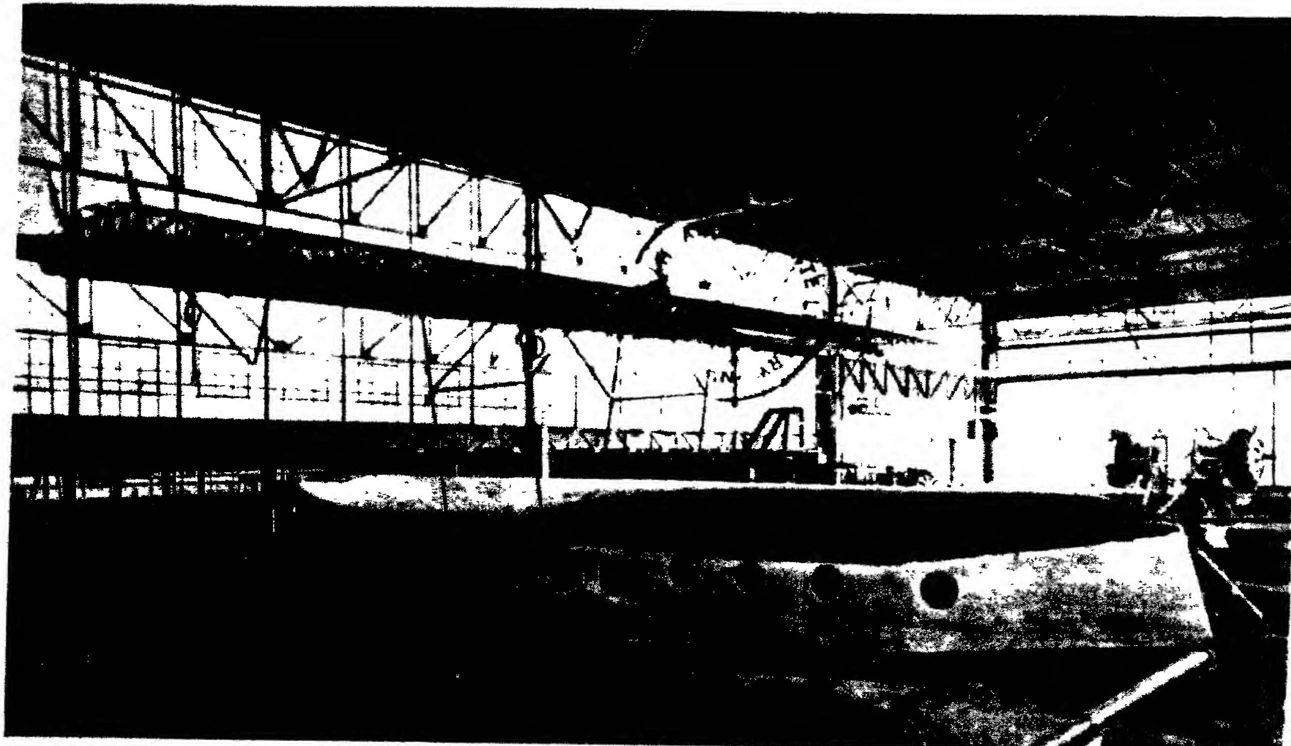
These lines are not written as an alibi. No alibi is necessary. The purpose is to explain the true cause of a great tragedy. Few people realize how many serious aircraft accidents of that character were caused by similar circumstances—by the pressure of commitments and publicity which make postponement impossible.

After the whole thing happened, some criticism was expressed at our not having called off an attempt which was considered dangerous. But if a precise expression were to be used, the word "dangerous" or the word "safe" would be inappropriate. Flights of such nature at that time were, in general, serious and involved hazards. Besides that, additional hazards were present in this case because some important load tests could not be completed and because the crew had no chance to become thoroughly familiar with the plane in overloaded conditions. Yet a successful flight was entirely possible and calling it off for these reasons seemed impossible after the extensive publicity that was given to the project.

As the zero hour approached, excitement became ever greater. Large numbers of visitors gathered in or around the place at all times. On September 15th the weather appeared favourable and Captain Fonck decided to start. The plane was loaded with petrol, but at the last moment a small leak developed in one of the fuel tanks and the attempt was called off. This minor trouble was quickly fixed, but the break in the weather was lost, and for the next several days weather reports from the mid-Atlantic were unfavourable. It was a restless time, and difficult to concentrate on any other work.



The S-38



The S-40 Flying Clipper being assembled in the Bridgeport Factory

On September 20th, the weather reports looked brighter, but apparently this was a short interval between two periods of unfavourable weather, and if a start were not made it would have to be postponed indefinitely. A short conference was held in our hangar on Roosevelt Field late in the night of September 20th, and it was decided to prepare the ship for the flight and to start early in the morning, provided the last weather reports before daybreak were encouraging.

After this conference, Captain Fonck, Lieutenant Curtin and the other members of the crew left the hangar for a rest while the other men, including myself, remained at the field to prepare the ship. It was a dark night. Taxi-ing with a heavy overload was not wise and, therefore, it was decided to load the plane with maximum fuel after it was placed at the end of the runway. Around midnight I climbed into the pilot's cabin and carefully and slowly taxied the huge, beautiful ship to the end of the runway, where it was turned and the pumping of the fuel begun.

It was a black September night; the sky was overcast, but there was no wind at all. The end of the runway and the plane were flooded with several powerful electric lights. Almost the whole night was spent in pumping the huge load of about 2,500 gallons of petrol from the barrels to the tanks of the S-35. Time and time again I went to the top of the small hill at the edge of the field, hoping to find some wind. Even a little breeze in the right direction along the runway would have greatly assisted the take-off. But there was none at all. Meanwhile, many hundreds of automobiles arrived on the field which, towards the end

of the night, became rather crowded. Shortly after four in the morning, we phoned for the last weather report. The information received indicated that for the next twenty-four hours reasonably good weather could be expected over most of the North Atlantic along the proposed Great Circle route. Bad weather, however, appeared to be closing in, and for many days afterwards the flight would not be possible. This information was relayed to Captain Fonck, and the final decision was made to start just before daybreak.

About five o'clock the plane was ready. By that time there were thousands of people all over the field. Driving a car along the runway, some of our men succeeded in clearing a strip of the field barely sufficient for the plane. Soon afterwards, Captain Fonck, Lieutenant Curtin, Lieutenant Islamov and Mr. Clavier arrived at the field and went on board the plane. I tried to get away from the crowd, and again climbed the hill at the edge of the field. The engines were started, and a few minutes later the plane was released and began to move heavily along the narrow space between two rows of spectators. At that time I made my last observation of the wind and to my great dissatisfaction I could feel a slight breeze in the direction in which the plane was moving. When the ship was about half-way along the field, something happened to one of the auxiliary landing gears, which either broke or was partly released, but remained for a time attached to the plane, dragging along the ground and leaving behind a cloud of dust. A few seconds later the plane reached the end of the field, went down from the steep edge, and for a moment disappeared.

Shortly afterwards a huge red flame and a dense cloud of black smoke shot up.

There were several causes for the unfortunate event. The conditions of the take-off were unfavourable because of a complete absence of wind, and, I believe, even the occurrence at that time of a slight tail breeze. The damage to the auxiliary landing gear and its resultant dragging along the ground slowed down the plane somewhat, and consequently it reached the end of the runway slightly below the necessary take-off speed. Captain Fonck told me that he could sense the trouble but he considered it impossible to throttle down the engines and try to stop the ship because, without power, the plane would have got out of control and would probably have run into the crowd. Aeroplane brakes were not in existence at that time. The plane was not seriously injured by landing after a short jump from the edge of the field, but some of the tanks were damaged and leaking petrol became ignited, probably by contact with the exhaust tubes. Captain Fonck and Lieutenant Curtin succeeded in getting out of the cockpit when the fire started. They made every effort to rescue the other two members of the crew, but the flames soon forced them away. Two fine men lost their lives, and the ship was, of course, completely destroyed.

When such an event takes place, there is usually a well justified desire to find the exact cause of it and to fix the blame. In this case, however, a single definite cause could not be established. At that time we were convinced we could take off with such a load, and later proved it. Once in the air the plane had enough fuel on board, and under the control of Captain Fonck

and the other gallant members of the crew, had good chances of reaching its destination. A slight breeze in the right direction, or a slightly longer runway, would most probably have permitted a take-off. On the other hand, a series of take-off tests before the final attempt would have permitted checking the auxiliary landing gear and establishing under safe conditions the best take-off technique. If the distance of the runway had proved inadequate, which I do not believe was the case, it would have indicated the necessity of building a hill at the end or assisting in some way the starting of the ship. However, all this required time which was not available.

Greatly disappointed and saddened by this disaster, we took the old S-29 and moved it into the now empty hangar. An ambitious enterprise that had a fine chance of becoming a success, became a great failure. The future was again filled with gloomy uncertainties. But the little group still had the determination to work and fight with adversities until success of a more permanent nature could be achieved.

XVIII
THE S-38 AMPHIBIAN

WE could hardly have survived that heavy blow had it not been for the fine, courageous and loyal support of our New England friends, and of the personnel in the organization. Perhaps the bitterest misfortune was the loss of the two men, Lieutenant J. Islamov, one of our important members, and the Frenchman, Mr. Clavier, radio operator for Captain Fonck. Extremely hard also was the loss of the beautiful S-35, which was by far the most important aeroplane designed and built by myself in the United States up to 1931, and which most probably was, in general, the leading ship of its class at that time. After it had burned, the performances of the ship were often questioned as having been impossible. Even though we were confident of the accuracy of the measurements and even had some test reports signed by outside witnesses, the absence of the ship made it difficult to make any use of the success, which was practically buried with the ship.

The financial situation of the company was obviously deplorable. At that time there was no possibility of insuring the ship and it was a total loss, the major part of which fell on our organization. All our capital was spent, and in addition there was an indebtedness many times in excess of our assets. The

first few days after the loss of the S-35 were spent in liquidating that tragic affair. There was an investigation which cleared Captain Fonck, as well as everyone else, of any responsibility in the accident.

Early in October, we began to make new plans. The situation of the company had not been particularly brilliant even before that and by now it was generally regarded as utterly hopeless. With the beautiful S-35 completely wiped out of the picture, the S-29 somewhat worn out and obsolete, the remainder of the equipment and property of questionable value, the situation really appeared as bad as it could be. Nevertheless a new plan of action was decided upon. Whether or not the performances of the S-35 were accepted by others, the men connected with the organization knew very well what they were and, as well as in the other branches of technique, a successful achievement in the past represents the greatest assurance for the future, even if an accident should temporarily interrupt progress.

By the end of 1926, we were again trying hard to regain lost ground. At that time we were working on the completion of the S-34 twin-engined amphibian and on another large twin-engined plane, the S-37, which had been ordered by Captain Fonck, who, with new backing, was planning another trans-Atlantic flight for the early part of the following year. It was during this time that we found it necessary to improve our shop facilities. Consequently, part of a factory in College Point, Long Island, was rented and we moved there, having, however, rented hangar space at Roosevelt Field. Partly by feeling, and partly by knowledge, we were confident that the time was

approaching when the United States would be awakened to the possibilities of aviation, which would give us an opportunity to succeed.

By the spring of 1927, the S-37 twin engine transport plane was completed. The tests proved that this ship was entirely suitable for the trans-Atlantic flight. The desired characteristics, namely, good take-off and considerable flying range, were unquestionable. In order to eliminate the hazards that proved fatal with the S-35, an elaborate series of tests were decided upon. The ship had only its service tanks filled with petrol, while the large tanks behind the engines were gradually filled with water. Provisions were made to drop the water at any moment during the flight, or even during take-off. This arrangement permitted us to start with a reasonable load and to increase the load after every flight. When the loads became substantially above normal, it was possible, once the ship was in the air, to drop the water so as not to subject the landing gear to excessive stresses. This method eliminated the risks and determined the ability of the ship to take off with the necessary overload.

While all this work was in progress, one of the greatest events in American aviation took place, the wonderful solo flight of Colonel Charles A. Lindbergh across the ocean on May 21, 1927. This flight marked one of the most important epochs in the history of world aviation, and also had a great and favourable influence on the development of aviation in the United States.

As a result, however, the most important reason for the flight of Captain Fonck was lost and the whole project died. The plane, which was at that time the

property of the group who financed Captain Fonck's attempt, was eventually sold. It made an excellent flight from the United States to the Argentine and was extensively used for carrying passengers across the Andes.

The summer of 1927 found us still struggling hard for a place in aviation.

In spite of the excellent characteristics of the S-37, the time for the large transport was not yet at hand, and it was impossible to secure more orders on this type of ship. We built and sold a number of Universal wings which did not represent any important business. The S-36 was completed and proved to be a quite satisfactory twin-engined amphibian. A few ships of this type were sold, one of them to the United States Navy. All this, however, was not steady work. The volume of sales was insufficient to keep the organization alive, and difficulties and worries were to a large extent, still with us. Yet the S-36 showed extremely desirable and interesting characteristics which could be achieved from a good twin-engined amphibian. This ship, the first practical and serviceable amphibian that we produced, supplied a vast amount of experience, and we felt ready to produce a still better ship of this class.

The interest and enthusiasm created by Lindbergh's flight influenced the state of mind of many people in the United States, and a rapid development in aviation appeared to be round the corner. This being the case, we determined finally to make one more effort to create a new plane, which would combine amphibian characteristics with the take-off performance and other qualities of land-planes of that

period. Furthermore, in view of the importance of time, it was decided to build not one but a series of ten ships of this type.

During the early months of 1928, we were busy with the construction of the S-38, which was designed as a ten-seater amphibian, with two 400 h.p. Pratt and Whitney Wasp engines. Conditions were still difficult but somehow, by intuition and foresight, we were convinced that real success was not too far away. The S-38 was completed during May, 1928. It was tested, and we very quickly realized that we had a really excellent machine on our hands. The ship had very good take-off characteristics from land and water. It had a climb of 1,000 feet per minute fully loaded, and a maximum speed close to 130 miles per hour. The ship could cruise nicely around 100 miles per hour, and it stayed in the air on one engine. All these features were excellent for 1928 and at that time there were no other amphibians with such performance characteristics.

Soon afterwards the S-38 was flown to Washington for a demonstration to the Navy and produced a very good impression. After the test flights, the Navy pilot declared that the performance of the S-38 was better than that of any other ship of its size and power. Almost immediately the Navy Department ordered two planes. Soon afterwards Pan-American Airways purchased some of the S-38's, and used them to pioneer their air-lines. It was this modest aeroplane which actually completed the peaceful conquest of nearly all of South America for the United States air-lines. Several private orders followed. The first series of ships were sold out quickly; a second series of ten ships

were started, and also sold out in a very short time. Soon afterwards the company found itself with more business than it could handle.

The factory was enlarged, and it became advisable to reorganize the Sikorsky Manufacturing Corporation. This was completed by the establishment of the Sikorsky Aviation Corporation, with a capital of five million dollars, which took over the assets and business of the former company. A sufficient amount of capital was quickly subscribed to permit us to purchase land in Stratford, near Bridgeport, Connecticut, in close proximity to deep water, which was very important for our seaplane activities. An excellent, modern aircraft factory, with first-class machinery, equipment, offices, draughting rooms, research laboratories and a wind tunnel, was planned and, during the year 1929, was erected on this land. It was at that time that our organization ceased to be a small one, and became a substantial, excellently equipped modern aircraft manufacturing organization.

In 1929, the Sikorsky Aviation Corporation had the good fortune to become first a subsidiary and later a division of the United Aircraft Corporation. At that time there were other alternatives but my associates and I were strongly in favour of United Aircraft Corporation, because we felt that this fine, progressive and substantial organization which combined engine, propeller and aircraft manufacturers and at that time even air-line operation, were a group which would permit us to develop to the best extent our inherent possibilities. I have been happy and proud, during these past years, of my association with one of the greatest and finest aircraft concerns in the world.

During 1929 and 1930, a large number of S-38's were produced and sold. Altogether over one hundred ships of this type were built and delivered. In 1929, an S-38 was used by Colonel Lindbergh to inaugurate air mail service between the United States and the Panama Canal. Later on, these ships were used for the pioneering and operation of about ten air-lines, among which were the Pan-American Airways, Pan-American-Grace Airways, Inter-Island Airways, Curtiss-Wright Flying Service, Colonial Western Airways, Canadian Colonial Airways, NYRBA Lines. In addition, many private individuals were using the S-38 with satisfaction. This type of ship was later used on many exploration flights, among which was one by Mr. and Mrs. Martin Johnson, who flew in the heart of Africa. During this trip they made a moving picture in which their plane was prominent.

I made a considerable number of flights in the S-38, which I enjoyed greatly. Among the most interesting was one early in January, 1931. At that time the Government of Chile was expecting a visit from the then Prince of Wales to their country and ordered an S-38 amphibian to furnish transportation for their guest to various inaccessible parts of Chile. The ship had to be ferried from Bridgeport to Santiago, Chile, a distance of some 7,000 miles. I decided to use this opportunity to make a trip in the ship, at least part of the way.

On a morning in January, 1931, which was bitter cold, we took off from the ground from the Bridgeport Airport, since the water was covered with floating ice. A few hours later we arrived in Miami, and the next morning landed in warm, tropical Havana, where

we went for a swim. This ship had no radio on board, and therefore, we preferred to continue the flight from Havana over the open sea and over inaccessible parts of Central America, following closely a regular Pan-American Airways southbound air-liner. This ship was another S-38, which was very pleasing to me. During the flight I spent most of my time behind the controls of this excellent, manœuvreable aeroplane. It was interesting to fly over unknown country above the clouds and around the mountains and volcanoes of Central America. During this part of the trip we needed no navigation, because we simply trailed the other S-38 that was flying ahead of us.

We spent a comfortable night in the home of a representative of the United Fruit Company in Tela, Honduras. The next morning we hopped off from Tela on a flight of two and a quarter hours duration for San Salvador, having crossed high mountains and inaccessible lands of that part of Central America. I was later informed that it takes about two weeks to travel between these points by any other means. We continued our flight to the Panama Canal, where I had to leave the ship with regret, because lack of time did not permit my going farther south. Captain Sergievsky continued, delivering the plane to the Chilean Government. After giving the necessary instructions to the Chilean Military pilots, he returned north. Later we learned that the plane was extensively used by the Prince of Wales, who was well pleased with its flying characteristics.

A great deal of flying was done by the S-38 planes in all parts of the world by private owners and by air-lines. In the United States the Army and Navy

both had a substantial number of these planes. It is believed that these planes made a total of over 25,000,000 miles, or roughly, one thousand times round the world.

XIX

THE FIRST AMERICAN FLYING CLIPPER

AS a result of the success of the S-38 the opportunity came to me to resume the construction of large planes of which I dreamed as a boy. Failure and discouragement had given way to accomplishment so rapidly that I did not have time to think much of our good fortune. When one begins to succeed he has all he can do to keep up with his work and dreaming is tempered by action. But, nevertheless, it was with a feeling that something new was to take place in aviation that I learned Pan-American Airways had asked for the construction of a much larger air transport than was then in existence. They had made a courageous and far-seeing decision. The traffic was growing and they believed that larger and more luxurious aircraft were needed rather than an increased number of small planes. This was considered a better engineering solution of the problem, as well as a better way to satisfy the passengers.

Our organization was finally chosen by the Pan-American Airways to produce this flying ship of novel characteristics. It was the important and progressive engineering work on this project which gave me an opportunity of meeting and later co-operating with Colonel Charles A. Lindbergh. During several con-

ferences in the Pan-American office, as well as at the plant, general requirements for the ship were finally decided upon and the work was then started.

The planning and construction of the S-40 Flying Clipper presented several new and difficult problems of design and research engineering. For instance, when the landing gear was designed it was hard to find the necessary springs for the seventeen ton aeroplane which had to be supported by two wheels. We were unable to locate any that would be powerful enough to take the load from aircraft or automobile source. Finally, however, we looked over the source of supply of railway car springs, and found the ones we needed to be nearly the same as the springs used in a medium size railway car.

While the work was in progress, serious doubts were sometimes expressed as to whether an amphibian of this size could be built. No one at that time had questioned the possibility of constructing such a seaplane or land-plane, but the gross weight of seventeen tons was considered too much for an amphibian, which was generally looked upon as a reasonably light aeroplane.

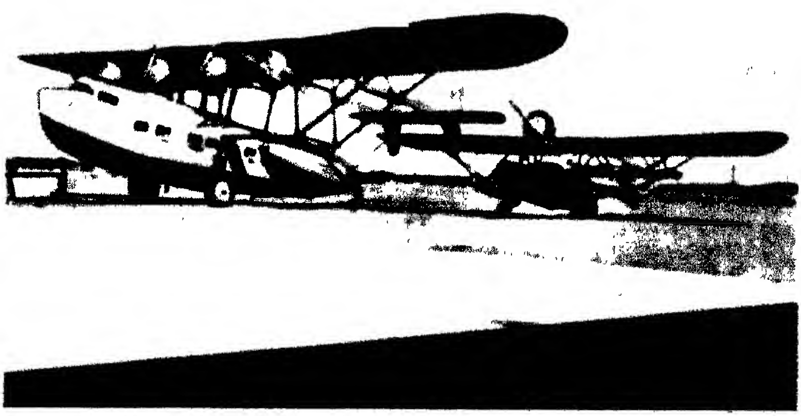
As the design progressed, we had time and time again to meet novel problems. One such case was the proper location of the pilot's cockpit with reference to the whole aeroplane. In a large ship of such size we considered locating it in the middle, or putting it in the centre section of the upper wing, or in the bow of the boat hull. Important advantages appeared behind each of the ideas, and for the time being a satisfactory decision was difficult to reach. This being the case, I made arrangements to see Colonel Lindbergh, who

was technical adviser for Pan-American Airways, to ask his opinion on the question. A few days later a meeting was arranged between us in New York at the Pan-American office. I had blueprints of the ship with me and briefly described the problem to him and the general arguments brought up by some of our engineers and pilots in favour of the few solutions that were proposed. Colonel Lindbergh listened to all this quite attentively; then a few moments later, in a simple and modest manner, he gave his own opinion. As I listened to his argument, I realized immediately the clearness and good foundation of his advice. I was really surprised, at that time, how quickly he was able to grasp all the major and probably most of the secondary factors and how perfectly he could distribute them in the order of their importance. As I followed his ideas, I had not the slightest doubt that he was right.

I returned to the factory and gave orders to continue the design along the lines suggested by Colonel Lindbergh. At the time of the conference and many times later after the ship was completed and during test flights, I realized the correctness of the decisions that had been made in accordance with his advice. The cockpit is where he said it should be, about one third of the way from the wing to the bow.

The period of construction of the ship was very interesting. It was exciting to watch the huge spars, the ribs and finally the great wing being assembled, as well as the roomy boat hull gradually taking shape. Often in the evening several of our engineers, including myself, got together in order to check the progress of the work, and to study the impressions and probable

The S-40 ready for test



The seventeen-ton S-40 Flying Clipper and the two-ton S-39 Amphibian

[Courtesy of Pan-American Airways

The S-40 American Clipper in flight

characteristics of the ship under construction, as compared to the original ideas and sketches from which it had actually evolved. Knowledge, experience, as well as imagination and intuition, were needed in order to detect as early as possible any of the factors which, while being calculated on the basis of the best information available, could still eventually bring trouble.

Early in 1931 the big plane was assembled and nearing completion. Frequently I stayed at the factory late at night thinking about the ship, its details, the programme of tests and the possible troubles that we should foresee. Once again we could feel gratified in watching one more ambitious dream materialize. It was grand to stand before a nearly completed aeroplane, and to attempt to recall the impressions created by the early ideas and sketches of the ship before it was built, or even designed.

Early in the spring of 1931 the ship was finished, and after an extensive check and inspection of its structure and aerodynamics, I released the ship for test flights. It was a pleasant moment for all of us, who were at that time on board a motor-boat, to have the sensation of worry, or at least of tenseness, replaced by joy and triumph at the sight of the fine, big ship easily and gracefully taking off. The tests of the S-40 were successful and soon afterwards it became possible to make extensive performance and demonstration flights, which fully confirmed the expected characteristics of the ship in the air, on the water and on the ground. When all tests were completed within a reasonable period, the S-40 was returned to the factory. Flights were suspended for a couple of weeks while the plane was repainted, and all interior upholstery, carpets,

seats, window curtains and various objects of equipment were installed. Soon after, the flights were repeated. My impressions of one of these over New York, which was my first in the S-40 after installation of the upholstery, were mentioned in the beginning of the book.

On October 12, 1931, the S-40 flew to Washington where it was christened by Mrs. Hoover, the wife of the President of the United States at that time, and received the name of "American Clipper." We feel justified in considering the American Clipper the forerunner of a series of other glorious Clipper ships that established American air-line operation across all oceans.

Late in the autumn, the Pan-American Airways accepted the American Clipper and flew it to Miami. Its maiden flight was arranged as a cruise from Miami to the Panama Canal. Probably because the captain of the ship during this voyage was Colonel Lindbergh all available seats were purchased almost immediately after the cruise was announced. I did not want to miss the opportunity of participating in the first flight of this ship, and made arrangements for a reservation. In November the American Clipper, piloted by Colonel Lindbergh and Captain Basil Rowe, with a full number of passengers, took off from Miami. The start was delayed and, therefore, a stop was made overnight at Cienfuegos, Cuba. In the evening the crew, both pilots, mechanics, purser, radio operator and myself had dinner together.

During this time I had an interesting and constructive discussion with Colonel Lindbergh and Captain Rowe on the subject of a still more efficient and re-

fined aircraft of the Clipper type for trans-oceanic use. Even the little experience which was made available by that time by the American Clipper was sufficient to convince me that we could build more efficient ships capable of carrying fuel for long distances, which would eventually become real equipment for trans-oceanic air travel. Several of the points and ideas that were brought up during that dinner, and later in the flight, were eventually used as a basis for the development of the next trans-oceanic flying Clipper.

Our next overnight stop was in Kingston, Jamaica. After the landing I had an opportunity to observe some of the other activities of Colonel Lindbergh and to admire his unexpected ability in a totally different field. The first was the quite complicated problem of arranging the schedule for the future flight of the ship, a schedule which had already been changed by our delay. While I was busy on the ship writing down some of my engineering observations of the flight, I could hear, and once in a while watched with interest, the whole series of telegrams which were sent from the ship by wireless. Colonel Lindbergh had to radio Miami, then to the New York office, then to Barranquilla or the Panama Canal and then again to Miami, until finally the schedule could be brought into correct shape again. I left the ship before this was done, went to the hotel and had a chance to get a rest before the dinner to which Colonel Lindbergh, Captain Basil Rowe and myself had been invited.

This dinner was arranged, as far as I remember, by the Chamber of Commerce in Jamaica. I was told that nearly all of the prominent residents of Kingston and of Jamaica were present. Some three hundred

people assembled in a large hall. The Chairman of the Chamber of Commerce made a friendly and interesting speech of a general nature for about half an hour, touching on some political questions, the progress of aviation and welcoming the first large flying Clipper, and its captain, crew and passengers. The reply had to be made by the captain of this little expedition, who was, of course, Colonel Lindbergh. I know that he had had no chance to think about his speech, yet without any preparation, he stood up and talked for half an hour. I do not believe that an experienced diplomat could have done better. He replied to the former speaker, and gave his own ideas as to the value of air transport for Jamaica because of its geographic location at the cross-roads between North and South America. I was really surprised to see how quickly Lindbergh grasped the situation. His talk was followed by long applause from the whole audience.

The cruise continued without any trouble, with stops at Barranquilla, South America, and finally at Cristobal, near the Panama Canal. The return trip was made along the same route.

XX

THE DEVELOPMENT OF AN OCEAN AIR-LINER

WHEN the design of a new aircraft is under way, there is a feeling among the engineering personnel that it is the best that can be produced, and that in the future it will only be necessary to refine and improve the details. I heard such opinions even in 1914. In spite of the enthusiasm which we all had during the design of the S-40, this feeling was not present. We all realized that a more advanced design of aircraft could be made, but I had a definite reason to be careful, and even conservative, when the general characteristics of the S-40 were determined. The realization that it would sooner or later be extensively used to carry a large number of passengers entered very much into my decisions. It was this fact that forced me to resist the temptation to build the new ship along more advanced lines.

By this time, my experience and knowledge were sufficient to impress upon me the fact that too much novelty in a design, which already included serious departures from the conventional, represented a great risk. That was the reason why we took as a model for the S-40 the reliable S-38 amphibian, which had been thoroughly tested and was known to possess excellent safety and control characteristics. Accordingly I decided that it was worth while to sacrifice a possible

increase in speed or a more modern appearance for the really reliable, thoroughly tested features of a well established design. I realized well that the size of the ship and several other unusual features would offer enough problems in design and would also keep the flying and operating personnel busy.

But now, having taken this step, it appeared that we could include many improvements in the next one. This I considered sound because the next proposed flying Clipper ship was again a four-engined aircraft of the size of the S-40. Therefore at least the size, weight, power and various other design and operating elements could be considered as well known. It appeared safe to make as large a step forward as we could in refinement of design. This was also necessary in order to fulfil the difficult requirements proposed by Pan-American Airways for their next flying Clippers.

These included a lifting capacity which would permit carrying fuel for a 2,500-mile non-stop flight against a 30-mile wind, at a cruising speed far in excess of the average operating speed of any flying boat at that time—a difficult problem.

I believe that we were the first company that accepted the challenge and also the first to complete the work and produce a ship filling and exceeding the specifications. When starting this job we fully realized the seriousness of the problems before us. We also realized that we had to step above and beyond several established factors in aerodynamic design in order to do what many authorities in aviation considered impossible. Ideas about this advanced design had been expressed in our engineering department for a long time, even during the construction of the S-40, but we

now faced the necessity of using them in order to combine a considerable flying range with a higher cruising speed than ever before, which called for the highest possible efficiency of the aircraft. Translated into the language of the layman, it may be called a quality which would obtain the greatest possible work from every gallon of fuel on board, from every horse-power delivered by the engines, from every cubic foot of displacement of the boat and most of all from every square foot of its wing surface. The latter being the case, we must produce a craft which would carry more pounds per square foot of wing than usual. The very heavy wing loading was one of the first and important innovations in this ship. Most of the planes of that time had a load of fifteen to twenty pounds per square foot, often much less. In the S-42 Flying Clipper we went up to about thirty pounds per square foot and expected to get away with it in spite of the serious doubts that were advanced. To make it possible, however, we had to produce a new type of high lift device that would increase the lift of the wing to a certain extent for a landing. This was done by means of a new type of flap mounted along the rear part of the wing. A large number of other problems of aero-dynamic, hydrodynamic and structural character also had to be solved while the new trans-oceanic flying Clipper was designed in 1932 and went under construction in 1933.

As for the hydrodynamic features of the large boat hull of the S-42, a friend of mine once asked me if I had copied it from a whale. He had been in the American Museum of Natural History and, standing in front of the whale which is suspended there from the ceiling,

he noticed how similar was the contour of that animal to our flying boat hull. We had not consciously followed the whale outline, having determined the shape of our hull by tests of models in tanks, but it is interesting that we should have arrived at a shape similar to that which nature devised in stream-lining this largest of all swimming creatures.

The effort of a modern aircraft designer who attempts to produce a novel and progressive type of ship, and of the group of engineers working on a project, is first, of course, to create the general outline of the ship, and to combine in a proper way the various factors, assigning the proper place for each part in accordance with the relative importance of the same in the complete machine. A conception of the general design, combined with technical elegance and harmony in bringing the various separate elements together so as to produce a completely efficient machine, remains the major factor of success. The next factor, nearly as important as this, is the proper solution of dozens of major, and thousands of minor, engineering problems. It is the ability, experience and still to a certain extent, intuition, of the design engineers that enable them to make a good compromise between aerodynamic characteristics, structural weight, cost, and several other secondary requirements.

There is yet another group of problems that relate to aircraft operated from water. If we analyse a flying boat, we can see that we have what can be called a three-in-one machine of transportation. While afloat on the water or when moving at any speed up to twenty-five miles per hour, the flying boat is generally similar to a surface steamer and must fulfil several of the require-

ments of the small size steamship, for smooth as well as for rough water operation. When the flying boat moves faster, particularly between forty and sixty miles per hour, it becomes a totally different ship, with entirely different requirements to satisfy and problems of different character to be solved. For example, if the boat had several big holes in its bottom, it still would not sink because at such speed it is supported not by the displacement of water, as in a steamship, but by the striking force of the water which supports it dynamically. In this case, then, it is similar to a flat stone which may be thrown over the surface of the water, and which will not sink, but will make several short jumps, or even glide along the surface until its velocity is lost. Finally, as the plane accelerates further, the wing will carry a greater amount of the load and when the take-off speed is reached, the wing becomes able to carry the whole weight and the plane rises in the air. The proper arrangement of the elements of the design, so as to satisfy these three different requirements and insure smooth and orderly transition from one condition to the other, represents one of a multitude of serious problems which have to be solved. This solution gradually materializes in about two or three thousand drawings, from which in turn thousands of important, and hundreds of thousands of minor, parts, are built and finally assembled to produce the huge flying ship.

Some eighteen months of hard work went by, and the S-42 long distance flying Clipper ship was finally completed and launched. The steady efforts of a whole group of efficient men were well justified by the results, as can be seen from the following comparison. The

S-40 American Clipper, when completed in 1931, was a successful and satisfactory aeroplane that compared favourably with the best flying boats of that time. It could carry its normal load for about 700 miles and if this load were replaced by petrol, and only the crew and about 300 pounds of mail taken on board, the ship would have a range of 1,500 miles at a cruising speed of 115 miles per hour. Under comparable conditions the S-42 would have a range of more than 3,000 miles at a cruising speed of 150 miles per hour. If the two ships were to be judged on the basis of a flight for 1,000 miles then the S-40 would carry 3,300 pounds of pay-load, while the S-42 would carry 8,500 pounds of pay-load. Possibly a still more interesting comparison, because it eliminates the influence of engine power, would be the following one. For the same distance of 1,000 miles, the S-40 would on the average carry 1.35 ton-miles per gallon of petrol, while the S-42, travelling at much greater speed, would carry 4.25 ton-miles per gallon of petrol. This last figure demonstrated the progress and considerable increase in efficiency of the aeroplane which had been achieved.

It must be mentioned, however, that the credit for these results should not go to an individual or even to a single group. In this case it was the combined work of a great number of different persons, many of them outside our organization. It resulted in part from the excellent scientific data and even direct advice that were secured from the National Advisory Committee for Aeronautics. It represented a vast amount of important practical information contributed by the engineers of Pan-American Airways. It represented also a great deal of other scientific data secured from

other sources, and it was to a large extent the improvement in the Pratt and Whitney Hornet engines which permitted more power with less parasite resistance and a much lower specific fuel consumption, as well as greater reliability. Finally, a very important factor was the use of another outstanding American invention, namely, the variable pitch propeller. This type of propeller, the necessity for which was so fully and clearly understood many years ago, was finally made practical by the Hamilton Standard Propeller organization. It is the variable pitch propeller which permits utilizing to the fullest extent the power of the engines for the take-off, without sacrificing any of the potentialities of the power plant for normal cruising speed.

All these advantages, together with hard work and carefully directed efforts, enabled us to produce a ship which was substantially ahead of any other plane of this type then in existence in the world.

As the time for the completion of the plane came closer, a great many evenings and nights were spent by us in the well-lighted factory building, looking over the ship and trying to foresee any possible sources of trouble which might develop, particularly during the first flights. This was again a very interesting phase of the work, in which individual experience and imagination were sometimes still valuable, as in the old days. Mathematics, science and wind tunnel could in this case be considered as reliable servants and advisers only. It was necessary to feel or detect the possible source of trouble, and if this was correctly done the scientific information and perhaps a wind-tunnel test would permit checking; but to foresee trouble, personal experience was still needed. All this was particularly

important in a ship of such power and size. A minor mistake in a small aeroplane can be temporarily taken care of by the ability of the test pilot. However, the bigger the ship the less is the possibility of such correction, and the plane must be free from any pronounced defects, even in adjustment, from the very beginning.

The last part of 1933 was occupied by this kind of fascinating and, at times, troublesome work. The plane was completed shortly after Christmas, but it was very cold and the river froze so solidly that the testing of the ship was impossible and had to be postponed until March, 1934, when the ice was gone. Finally after the usual motor-boat inspection of the Housatonic River for floating ice between the factory and the open Sound, our pilot reported that he could make a test. As usual, it was a great event to watch the large, beautiful Clipper being launched on the water for the first time. We went on board for the first run soon after to check the water characteristics. Our test pilot carefully taxied the big ship down the river and into the open Long Island Sound, where he started to make manœuvres on the water, first at very slow speed and later gradually increasing the power. While this was going on we were busy observing the actions and the behaviour of the new ship from various places inside the long boat hull. Everything appeared satisfactory, and after a while the pilot, having completed the turns and low power tests, decided to go on to the next part of the programme, that is, get the ship on the step and let it accelerate under some forty to fifty per cent of power, in order to check the running on the step and the flight controls at thirty-five to fifty miles per hour speed. For this test I took the co-pilot's seat,

which offered a good opportunity for observation.

The throttle was opened and the lightly loaded Clipper, under a part of its 3,000 h.p., went on the step almost immediately and continued to run nicely and to accelerate in spite of the fact that the throttle was again reduced to some forty-five or fifty per cent of the power. From my seat in the cockpit it was easy to see how quickly and easily the large ship was gaining speed. The pilot did not have an opportunity to make many of the tests while running on the step, because a moment later we were in the air. This was a grand feeling, but a flight was not on the programme for that day, and therefore, the pilot throttled down the engines immediately and landed. This first hop lasted only a few seconds. A few more tests were made on the water, but without permitting the new Clipper to accelerate because of its exceptionally easy take-off. After that we returned to the factory. A conference followed the test, all observations were discussed and a real flight was decided upon for the next day.

In accordance with insurance regulations, only the test pilots and two mechanics were allowed on board. The ship took off easily and gracefully, and made a nice flight of some twenty minutes. It was entirely successful and was followed by several others. During the next two weeks we were extremely busy with the serious and important work of checking the main general characteristics of the new flying Clipper. During that time any serious deficiency had to be discovered and corrected. After the flights, often until late in the night, we discussed our observations. It took all our experience and good judgment to analyse properly what we had seen, and to determine whether

some trouble was serious or minor, or even imaginary. Work of such nature makes the senior members of an engineering group realize the weight of the responsibility which they have to carry.

A few more adjustments were made in the ship and early in April we were able to start serious flights, gradually increasing the useful load until the full contract load was reached. The S-42 performed according to our expectations, and could take off easily despite the very heavy loading.

I was usually on board during these flights. It was a glorious feeling for all of us when the ship was for the first time given full power for a speed test. We were flying low above the water over a measured course between two lighthouses watching the surface of the water rush by at an obviously high speed. Once in a while we would pass a boat, finally we would whizz past the lighthouse at the end of the measured course, after which the pilot would throttle down the motors and at the same time usually start a steep climb. The momentum of the large, heavy Clipper would permit it to mount several hundred feet even if the motors were stopped entirely. Having reached the desired altitude, the pilot would turn round and come back on the line about one mile from the beginning of the measured course. Then the engines would be given full power and the ship would accelerate to maximum speed. During the turn it was usually possible to make preliminary calculations of speed on the basis of the number of seconds taken for the flight between the two points, measured by stop-watches, usually by two independent observers on board. It was thrilling to make these calculations on board the ship that was

tearing through the air with wide open, roaring engines and find out that the speed of the big flying Clipper at sea-level was over 180 miles per hour, well above the contract guarantees.

On April 26th, only a few weeks after the first test flight, the flying Clipper, piloted by Captain Sergievsky and Mr. Raymond B. Quick, established a world record, carrying a load of 16,608 pounds to an altitude of 6,561 feet (2,000 metres). This altitude was required by the rules, but actually the ship reached 16,000 feet during this flight.

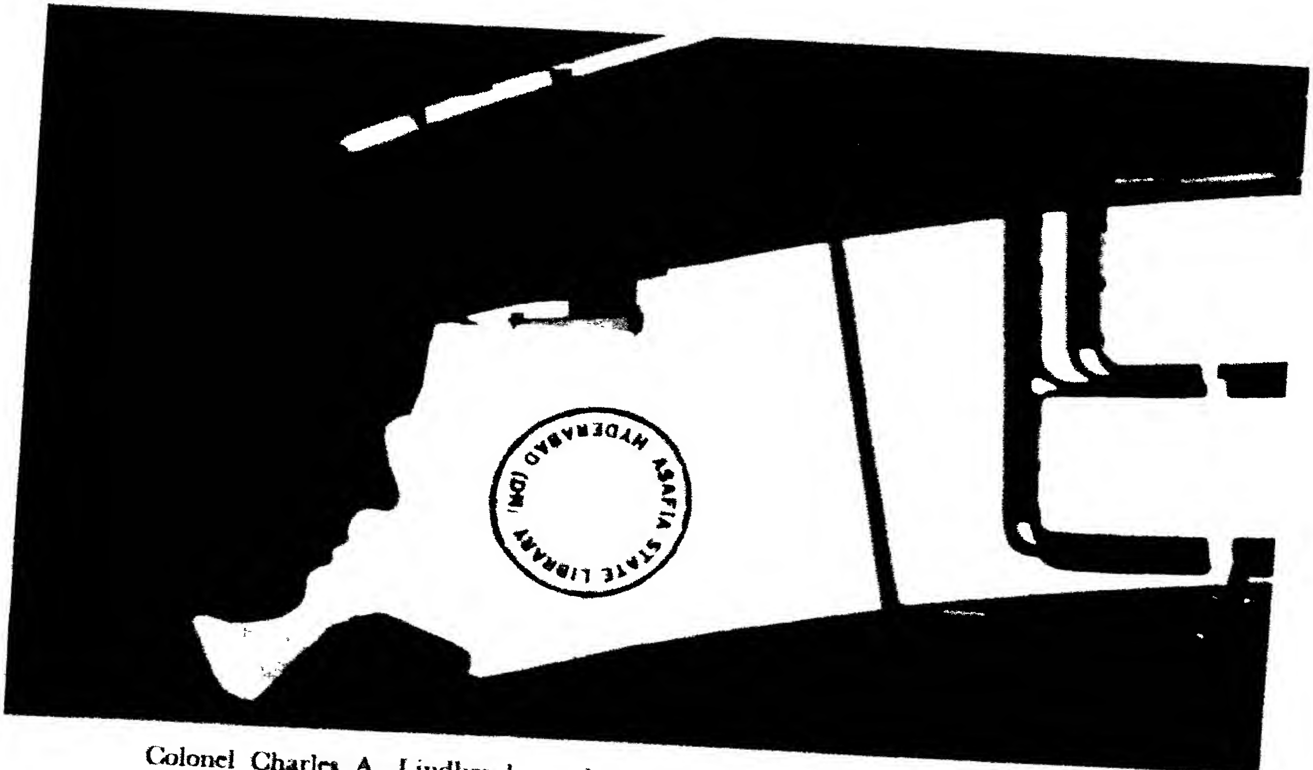
Various other flights were made during the latter part of the spring and the summer, including the establishing of one more world record for altitude with load. During July the test flights, as well as the installation of various instruments and operating equipment, were completed. In view of the fact that the combined speed, flying range and lifting capacity of the plane appeared well in excess of the highest performance of any other flying boat of that time, we decided to try to establish some world records, combining this flight with a good checking of the operating cruising speed, range and fuel consumption.

Before the officially recorded flight was attempted, we made a test run in order to check again the performance of the ship. The official conditions required four complete rounds of a 500 kilometre course, carrying two tons of pay-load, besides fuel, oil, crew and equipment. It proved to be a very complicated job to choose a course that would in every respect be satisfactory. The total length of the course or more exactly the sum of the distance between turning points could not be less than 500 kilometres, or about 311 miles, and

at the same time it must not be more than that because credit would only be given for 500 kilometres. The turning points had to be well established to enable the Geodetic Survey to certify the exact length of the run. Finally, they must be conveniently located and easily visible to the pilot of the ship, so that he could fly with the minimum amount of deviation from the course and make as close turns round the points as possible.

Captain Sergievsky, the test pilot of the organization, finally established the following course: A start over Stratford lighthouse, Connecticut, and turns round the western pylon at George Washington Bridge, New Jersey; the lighthouse on Staten Island, New York; Fire Island lighthouse on Long Island, New York; N.W. Cape on Block Island, Rhode Island; Point Judith lighthouse, Rhode Island; and back to Stratford lighthouse. The course was certified to be a fraction of one mile over 500 kilometres (311 miles), or almost exactly what was needed.

Late in July we made a preliminary run with the Clipper round these points. The weather was clear. We did not investigate in detail the direction and force of the wind, because for a preliminary test along a closed course this was not particularly important. As long as this was an unofficial flight for our own information, observers on board the plane did the timing. We took off, crossed the line over Stratford lighthouse at about 3,000 feet, and went towards the next turning point. To tell the truth, I was quite worried during the first quarter of an hour of this flight. We were going slow, far below what was expected. Of course, I hoped that this might be a strong head wind, but while on the ground before the start, I could not see



Colonel Charles A. Lindbergh at the controls of the S-40 American Clipper

The S-42 Trans-oceanic Flying Clipper

any fresh wind. It was reasonably smooth in the air, and in view of the slow speed while we were flying towards George Washington Bridge, a disturbing thought flashed through my head. What if our measurements were incorrect and the ship was not as fast as we expected? Without mentioning this to anyone, I watched the time myself, ready to transform quickly on my slide rule the minutes and seconds of the first leg of the course into miles per hour. Finally, we reached and turned round the New Jersey pylon of the George Washington Bridge. It was a beautiful sight, but, contrary to my custom, I did not pay much attention at this time to the scenery. I was busy with my slide rule and a piece of paper. The speed was not good; however, after the turn I immediately realized that we had had a strong head wind because the speed over the ground obviously became much greater, with a pronounced side drift. After the Staten Island turn it became a strong tail wind, and the speed again increased. After passing the Fire Island lighthouse I could check the average speed, which now appeared entirely satisfactory, and so all my worries were over.

The long, nearly straight line from Staten Island to Block Island, beyond the end of Long Island, was covered in slightly more than three quarters of an hour, at a speed which at times exceeded 200 miles an hour. The rest of the flight from Point Judith to Stratford was again considerably slowed down because of the head wind, but the average speed along the whole course was entirely satisfactory, well in line with our expectations.

Finally, everything was ready for the attempt to

establish at one time eight important world records, covering the combined speed over a given practical distance with a substantial pay-load. It may be worth while to explain briefly the meaning of the expression "world record." The following sentence is taken from the *National Aeronautic Magazine* of July, 1934: "With all the complexity of size and type, the F.A.I. record categories, developed over a quarter-century of aircraft performance, give a thorough and effective yard-stick for determination of just whose planes deserve the title of the world's best."

In the same copy of the magazine, an article was included inviting American fliers and manufacturers to establish world records as a method of proving the right of America to the title, "First in the Air."

The record flight was planned for August 1st, and an interesting coincidence happened on that day. The morning mail brought a letter from the President of the National Aeronautic Association, addressed to our organization, in which we were invited to attempt to establish world records.

Less than an hour after we saw this letter, the S-42 was starting on the record-breaking flight. Colonel Lindbergh, who was one of the pilots during this flight, had to drive almost the whole night in order to arrive on time, which he did. About nine o'clock, all preparations were completed. There was no hurry and the huge ship was gently lowered into the water, with all necessary fuel on board, all instruments and the properly checked pay-load of 4,400 pounds, which consisted of bags of sand and iron bars. A few minutes later Captain Sergievsky suggested that the other pilots and the crew go on board. Soon after, the engines

were started, and the S-42 went down the river. The few official observers, several newspapermen, and some of our engineers, including myself, went to the official starting point near the Stratford lighthouse to watch the beginning of that interesting and important flight. A few minutes later the ship took off and then disappeared in the haze of Long Island Sound, and four or five minutes later returned at an altitude of about 2,000 feet, flying directly towards the official starting line near the lighthouse.

The ship crossed the line at 9-24-28, and with its engines running smoothly and evenly at cruising power, soon disappeared in the haze in the direction of New York. We all went back to my office because we realized that it would take about two hours to cover the first round—four rounds being necessary for all records—and that we would have plenty of time to go back to the Point to watch the first passing of the ship. It was very interesting to follow the ship from my own office. A small radio station had been installed which permitted us to receive the messages that were sent frequently from the flying Clipper. In turn we were able to send our replies by a method which might appear strange, particularly at a time when the ship was almost in sight or when it was passing over our heads at the factory. We would get the radio messages directly in my office. Our reply would be received in two or three minutes by the plane, having been sent in this roundabout way. We phoned to the Pan-American Airways office in New York, they in turn telephoned to their main station in Miami, Florida, and the powerful radio station in Miami broadcasted the message to the plane. So our words had to travel

about 2,500 miles in order to reach the ship, which was sometimes only 2,500 feet over our heads.

The whole flight proceeded with remarkable exactness. From time to time we received information by wireless with reference to the number of revolutions of the engines, the power taken and the registered speed. Our Chief Engineer quickly checked the data and on his slide rule made calculations which gave almost exactly the time of arrival of the Clipper at the next turning point. In many cases the predictions were so remarkably correct that at about the moment his estimations showed the ship to be near or turning round some point, we received a radio message from the ship giving that location and at the same time a telephone message would come from the official observers informing us that the ship had just passed.

At 1-21-13 p.m., the second turn was completed. The S-42 crossed the line of departure near the Stratford lighthouse, and established in that moment four world records. Shortly before five o'clock we were all near the lighthouse to see the final crossing of the line. Again, exactly on time, the ship appeared above the hazy horizon like a huge silver bird. At 5-18-36 p.m. it crossed the line, completed the whole flight and established at one time eight records for sea-planes. The records established are as follows:

For a distance of 1000 km. (621·4 miles)

Speed	253·7 km./hr. (157·7 m./hr.)
Speed with 500 kg. (1102·3 lb.)	253·7 km./hr. (157·7 m./hr.)
Speed with 1000 kg. (2204·6 lb.)	253·7 km./hr. (157·7 m./hr.)
Speed with 2000 kg. (4409·2 lb.)	253·7 km./hr. (157·7 m./hr.)

For a distance of 2000 km. (1248·8 miles)

Speed	253·4 km./hr. (157·5 m./hr.)
Speed with 500 kg. (1102·3 lb.)	253·4 km./hr. (157·5 m./hr.)
Speed with 1000 kg. (2204·6 lb.)	253·4 km./hr. (157·5 m./hr.)
Speed with 2000 kg. (4409·2 lb.)	253·4 km./hr. (157·5 m./hr.)

The two records mentioned below were established on April 26th and May 17th:

Greatest load to 2000 m. (6561·6 ft.)	7533 kg. (16,608 lb.)
Altitude with 5000 kg. (11,023 lb.)	6203·6 m. (20,406·7 ft.)

Before leaving his office that evening, the president of our organization sent a reply to the president of the National Aeronautic Association which read in part as follows:

"On the morning of August 1st I received in the mail an interesting letter from you urging the industry to co-operate in a movement to return to the United States the majority of world records in order that the supremacy of American aviation might be measured by a readily understood yard-stick. At 5.30 p.m. on that same day, we were in a position to say to you that we had co-operated in the promotion of that movement, for on August 1st we returned to the United States eight world records to be added to the two already obtained by the S-42. By so doing, the United States now holds first place in the tenure of world records—exclusive of light planes—holding seventeen to France's sixteen."

Soon after this flight the ship left for the south, and later in the fall Pan-American Airways used this aeroplane to introduce a new schedule of air travel between the United States and the Argentine, cutting the total flying time from eight to five days. During the first flight a stop was made in Rio de Janeiro, and the plane was christened by the wife of the president of Brazil, receiving the name of "Brazilian Clipper." Not long after, the second S-42 was delivered to Pan-American Airways. This ship was equipped with large tanks which enabled it to cruise about 3,200 miles. It was extensively flight tested in Miami and early in 1935 was

flown to San Francisco. On April 17th, 1935, another important event occurred in the history of these flying Clipper ships.

In the afternoon of that day an S-42, called the "Pan-American Clipper," took off with ease from Alameda, near San Francisco, carrying a full load of petrol and oil, besides a crew of six and mail. The ship flew over the San Francisco Bridge, which was then under construction, and went straight out into the open ocean. Many times during that evening and night we thought about the ship which was flying somewhere in the darkness over the Pacific.

It was about eleven o'clock the next day when we again assembled in my office, listening to the radio and eagerly awaiting information about the flight. Not only a hundred, but even fifty years ago, such an event would have appeared an utter miracle, or an absurdity. Here we were in Bridgeport, near the Atlantic Ocean, listening to a broadcast describing the ship approaching, and later circling far above, Honolulu in Hawaii, describing its landing and taxi-ing towards the ramp, and a few minutes later telling us how Captain Musick and the rest of his gallant crew were stepping out of the plane in clean uniforms, carrying bags of mail and receiving the greetings and congratulations of the officials and numerous other persons who were present. Perhaps still more thrilling to us was to hear the familiar, quiet voice of Captain Musick, who said a few words about the trip. We all knew him and, of course, liked and respected him immensely. It was strange to hear his voice, as if he were in the same room with us, and difficult to realize the distance that separated us at that moment.

This performance of the plane gave us a feeling of great satisfaction. We recalled the many days and evenings of hard work, the worries and doubts, and were gratified to have a successful confirmation of our hopes. This was a good beginning. It was followed by the same flying Clipper gradually extending the route farther across the Pacific. Later on, another Pan-American S-42 inaugurated the longest over ocean air-line in the world from San Francisco to New Zealand. Finally in July, 1937, another S-42 Clipper made the first regular air-line crossing of the North Atlantic Ocean starting from the United States, flying first to England by the northern route, and then to Portugal by the Bermuda-Azores route.

The successful flights of the S-42 across both major oceans may be considered as concluding the pioneering period of aviation. They are also to a large extent the conclusion of the story of the Winged-S. The most important factor in this story is the creation of various types of large aircraft with four engines. This work actually began on September 17, 1912, and resulted, exactly twenty-five years later in the summer of 1937, in the successful commercial crossing from shore to shore of both major oceans.

XXI

THE WORK OF A PIONEER

THE successful flights of our Clipper planes were a source of real and permanent satisfaction to everyone connected with their creation, including, of course, myself. It was the actual beginning of the long predicted era of the universal use of aircraft for rapid transportation from any important place in the world to any other. It was also the conclusion of the interesting and even romantic pioneering period.

The pilot-designer of the early days had to create his machines on the basis of inventive ideas and the products of his imagination, but had no actual information on how to build or how to operate the machine. He sought guidance by creating his own theories of calculation, and his own crude home-made research equipment; by taking what was possible from other branches of technique and from nature, and adapting some for his own needs. There is no doubt that the advent of flying was to a great extent influenced by the development of the bicycle, motor-cycle and automobile. Apparently it is by no means a coincidence that a vast majority of the early aeroplane pioneers were connected as amateurs or professionals with bicycles or automobiles before becoming interested in aviation. The reason for this was that contact with these light, fast-moving machines supplied some information which

was indirectly adaptable to the construction and even operation of a plane, and to a certain extent it moulded creative imagination.

A young modern aeronautical engineer who starts his work well armed with a scientific education based on reliable research data and past experience, does not often realize the character of aviation pioneering work. It is about the same as stepping on board a palatial trans-Atlantic steamer for a five-day, pleasant and restful crossing of the ocean, and trying to imagine the difficulties and worries of Christopher Columbus sailing across the immense, completely uncharted ocean, towards some unknown end, guided mainly by faith, imagination and even intuition.

Here is an attempt by one of the few remaining pioneers of the early days of aviation to give some personal impressions of the character of this work. In many respects such inventive engineering work is similar to pioneering in other branches of industrial or scientific activity. But in other respects, it is different. There have been few other new inventions which have provided as much romance and thrill as the early flying machine, surrounded almost by an aura of mystery. There was also the serious aspect of early flying attempts, when the pioneer designer had to take off and rise in the air on the primitive, imperfect and dangerous, but usually beloved child of his imagination. Next would come the discovery as to whether the machine and the ability of the pilot, conformed with the then mysterious and mostly unknown laws of aerodynamics and flying.

Even elementary design data were not available. They had to be replaced by guesses and primitive

studies of various kinds, usually made by the designer himself and kept secret from the rest of the world. While some facts and a few sound theories were known in the period from 1908 to 1910, most of the information available was unreliable, often incorrect, and there was no way of separating the sound from the fantastic. This, in turn, created a strange conservatism in a field which should have been progressive and a tendency to rely on so-called common sense, a sense which was at times misleading. For instance, at a very early period, about 1907, Professor Joukovsky in Moscow discovered by wind-tunnel tests that a reasonably thick wing gave better results than a very thin one, a fact which has since been proved by test and experience. Yet this appeared so contrary to common sense that the vast majority, if not all, of the early designers, including myself, made the wings of their planes about as thin as possible, on the theory that a thin knife must go through the air more easily than a thick, blunt body. Now we know that a fairly bulky air-foil is in general better and that only in racing machines is a very thin wing practicable.

There was also an abundance of wires on early aeroplanes. Measuring the drag of these and calculating the substantial loss of power due to them, was easy even in the early period, yet to the eye, particularly in a drawing, the wires appeared so light and of so little resistance that they remained in most designs for a very long time.

Another more serious question was the location of the centre of gravity of a plane. To calculate its position on the drawing of a projected aircraft or to find it accurately on a finished aeroplane was, of course,

an elementary engineering problem. It was obvious that the centre of gravity must be close to, or coincident with, the centre of pressure of the wing. But the location of the centre of pressure was usually unknown with any degree of accuracy. When, for example, I designed the wings for all my early planes up to and including the S-7, I had no chance to study any of the characteristics of these wings. As a rule, when I designed a new plane, I would take a few sheets of paper and would draw one section after the other, trying to combine a curved front with a straight rear, until the section appeared good to the eye. When this was done, I would reproduce the section in actual size on a large sheet of paper laid down on the floor of our living-room. As for the aerodynamic qualities, I had no information at all. They had to be supplied by imagination and guess work. The situation was similar in the case of many other early designers. When a plane would crash, and in the early days this happened frequently, it would most often be found lying more or less nose down. This fact, together with a sort of natural feeling, which, in this case, was misleading, would prevent the early designer from placing the weight far enough ahead, because he guessed that the centre of pressure was located close to the middle of the wing. Now we know that this is not so, but the early mistake resulted in making the vast majority of early aeroplanes in Europe excessively tail-heavy, and therefore unstable and dangerous when speed was lost. In other words, they stalled easily, and fell off on one wing.

Many similar cases could be mentioned, yet, of course, engineering common sense was, and is, an ex-

tremely valuable source of guidance. Although this faculty could mislead, in the majority of cases it would work well. It is a faculty subject to training and development, by experience. This is obvious in almost any kind of human activity, but it was particularly important for the early designer. His own experimental data represented information partly written down and catalogued, partly held in memory. This data could be used for the verification of theories and it enabled the designer to create, with greater accuracy, machines of improved type. Another quite different result of experience was in the training of imagination and intuition, which helped to solve design problems when accurate data was not available. For instance, when I made the S-1, S-2 and S-3, I had no way of finding the centre of pressure on the wing and therefore could not calculate the forces on the tail, which with its supporting structure had to be built by guess. Yet it was also impossible to put too much strength in the structure of any part because the motors were heavy, propellers and wing sections were inefficient, and the plane had to be built as light as possible if it were to fly at all. Many of the early planes, including my own, had a load factor of not much more than two—that is, the parts were twice as strong as the normal stress we thought might be placed on them in calm air. And we guessed at much of that strength. This absence of information is present in many other kinds of development work, but the results of poor judgment in other fields are not apt to be so serious as in flying. The structural strength of the spars supporting the tail, as well as other important parts, must be right, or else . . . Remaining alive meant eliminating the

major mistakes, using every possible method for verifying the guess as to strength, and training the imagination and intuition so as to secure a reasonably correct answer when methods of correct analysis were not yet available. It often proved valuable to take the doubtful part in the hands to feel the weight, to try to bend a strut by hand. If some part of a plane under construction continued to raise doubts and suspicions, it was better to reinforce it. At a later date, when the aerodynamic characteristics of wings, and other data for calculation, became available, I learned with interest that in several cases such "guess" analysis actually arrived at reasonably correct conclusions.

This ability, acquired by years of work and endless verification, remains valuable even at the present time. Modern stress analysis represents a very extensive and complicated work that is usually carried on by specially trained engineers. For a flying Clipper they cover more than a thousand pages. Yet without even attempting an analysis, it is sometimes possible to discover an imperfection by looking at the part and simply feeling that it is not right or that a better design may be achieved. Nowadays this is not so necessary; a plane can be reliably and efficiently constructed on the basis of scientific data. But in the pioneering days, self-training, both in engineering problems and in piloting, was an important condition of success, and even of survival.

Sometimes a problem connected with unknown factors and conditions would be unsolved for days, remaining a source of worry. In the evenings, alone with the machine under construction, I tried to imagine the forces during flight under various con-

ditions, the possible abnormal loads created by the wind or by an imperfect manœuvre. On a certain evening, after long hours of working, my thoughts shifted away from technique and towards basic questions of life. Some sophisticated, and yet naïve, moderns consider that right or wrong are conditional conceptions, to be established and judged with relation to given circumstances, or political views. This logically leads to the conclusion that the difference between right and wrong is unimportant, and depends on the point of view. Such belief, in turn, creates a philosophy of life which at times is particularly convenient.

But in the case of aviation, which is not exceptional, the difference between right and wrong is not a question of opinion. The difference is positive and definite. Right means success; wrong means that the neck, together with most of the other bones, will be broken. Permitting myself to dream of the destinies of mankind, I thought how wonderful it would be if similar natural laws were to regulate some other branches of human activities. Take, for instance, the case of stubborn radicals with lust for power, who make a career and personal success by using wrong principles. How much better it would be if, as the result of wrong ideas, they would break their own necks rather than spread misery to a multitude of unfortunate, trusting people. What wonderful progress would humanity make if foolish and false ideas in philosophy of life and political economy eliminated themselves, with their creators, as completely as the mistakes of a pilot-designer eliminated him and his machine.

In creative engineering a misdirected imagination, of course, can lead one hopelessly astray. The early period, after the actual beginning of flying, was a time when a multitude of inventors and fanatics attempted to enter the field, often without any qualifications for success. The greatest failures and bitterest disappointments came from over-confidence and an uncontrolled imagination which the unfortunate inventor mistook for intuition. As a result, the inventor would disregard the study of former art, would not even try to verify his ideas and conclusions. In such cases there was invariable failure, and sometimes real tragedies.

I was visited once in 1911 by a serious, middle-aged lawyer. He suggested that I drop all my aeroplanes, which were already flying reasonably well, and then offered me a part in his own invention, which he assured me was far more efficient than any aeroplane then in existence. After closing the doors, and satisfying himself that no one was looking or listening through the keyholes, he produced a model of the invention. It was a sort of round metal box, with partitions inside. He was apparently surprised when I did not understand at once how it would work and that I did not show any enthusiasm.

"Couldn't you understand the value and importance of this great invention which is designed to surpass and eliminate all known types of aircraft?"

I said, "No."

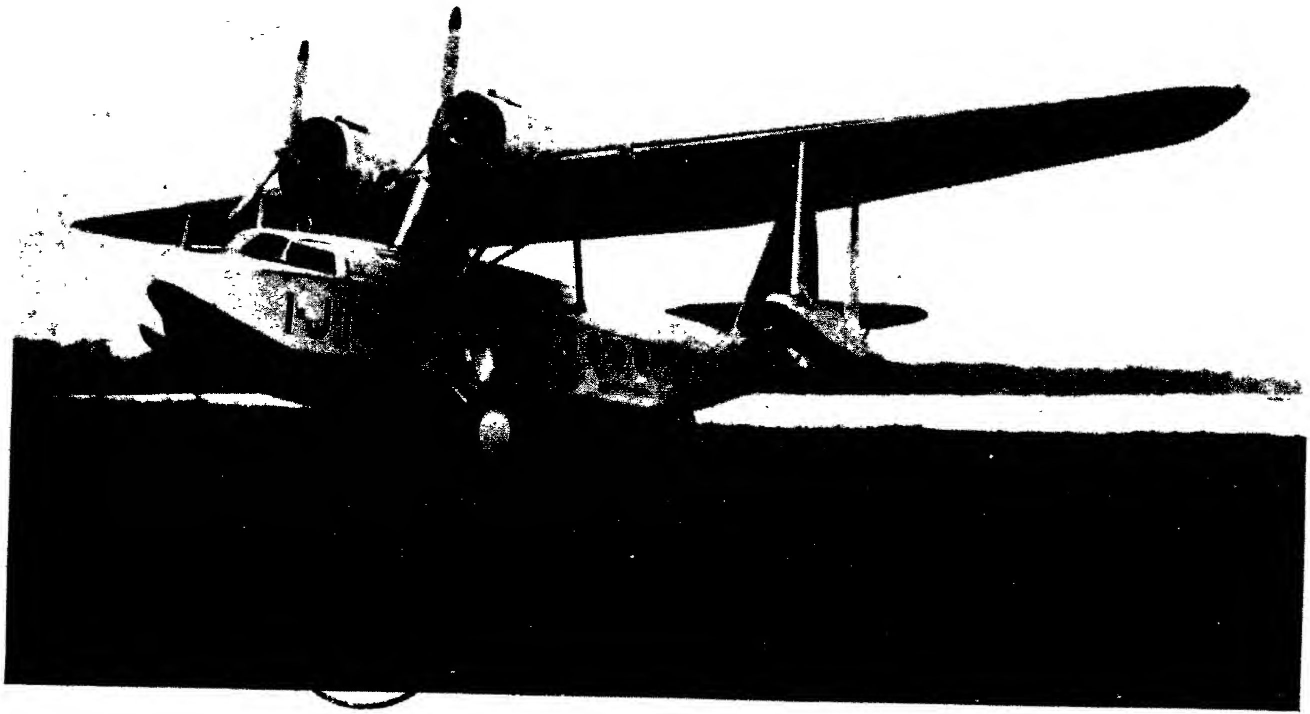
He continued, "The centrifugal acceleration can produce enormous forces. You know that a fly-wheel can be torn to pieces by this immense power. Do you know that a centrifugal pump can produce most any amount of pressure desired? Now if you will rotate

this box, the centrifugal force will produce enormous pressure on the sides of same which will be directed upward and which will give you a greater lifting power than any wing would ever be able to generate."

The mistake in the scheme was obvious. I tried to explain that the effect would merely be that of an inefficient centrifugal blower. I mentioned that the maximum lift created by a given power with a given cross-section of air stream can be reliably calculated and would in no way be near what he expected. However, with complete confidence, he replied that my computations were based on old mechanisms, such as the helicopter, while his discovery was a new and more efficient principle. The man had an attractive personality and I wanted sincerely to let him know the truth, to protect him from spending time and money on a thoroughly hopeless project. I suggested a test of his model with a ¼ h.p. electric motor I had in my room. He agreed, advising that I secure the motor tightly to prevent its being lifted in the air by his rotor. The model was fixed to the shaft, the motor was started and, of course, nothing happened. The inventor, however, was not discouraged. He simply said that apparently my motor was not any good. The real trouble with the man was that in spite of being educated and having some money for elementary tests, he was so confident that he considered research and study unnecessary.

This incident represents the imaginative faculty run riot, the result of uncontrolled day-dreaming. While the basic idea, the conception around which work is to proceed is indeed important, yet the value of it must not be overestimated. In most cases, ideas

Colonel Charles A. Lindbergh and the author on the wing of S-42



The twin-engine fifteen-passenger Sikorsky Amphibian, S-43

that eventually prove successful were known before they were properly materialized and made to work. The outstanding accomplishments in early creative aviation construction work were preceded by numerous unsuccessful attempts along similar lines. Frequently these failures helped to show that an idea was not workable. But most of the discoveries in any field of activity were at an early date considered impossible. Under such circumstances the pioneer must not become discouraged, but must, on the other hand, not grow over-confident and expect an easy success where only failure was known before. It is essential first to study the prior art and the failures. It must be established definitely how and why the designer-inventor may overcome the difficulties which formerly prevented accomplishment. Next comes the necessity of building as firm a foundation as possible under the projected machine, by reducing to a minimum the unknown or hazardous features, by calculating the action and stresses of all parts where possible, by utilizing available scientific information. This reduces the unknown and risky elements to a minimum, but in a really new pioneering work the unknown will always exist.

It was, I believe, Napoleon, who said that a good general is not one who never makes mistakes, but one who discovers them early enough and corrects them. This observation applies to the work of a responsible pioneer inventor. He must always be attentive, and create and train an ability to distinguish the sources of serious trouble from the unimportant, and concentrate his attention on the first. While he must stubbornly fight his way towards his objective, some-

times through the uncharted jungle of unknown facts and laws, yet he must have a flexible mind, ready to drop immediately an unhappy or doubtful solution, and to accept promptly any new fact or discovery, provided only that it is true. Truth is obligatory under all circumstances—it is never optional.

There are other factors necessary to the success of an inventor in a new field, such as hard work, courage and energy; the determination to drive ahead in spite of troubles, disappointments and financial obstacles. A certain technical knowledge is also required, and an ability to obtain information which is lacking, to determine what engineering work in other fields may be adapted to one's particular needs.

All this represents about ninety-nine per cent of the conditions that are necessary for success, but the remaining one per cent may be compared to the spark-plug in a motor. Take it out, and what is left is a dead engine. This spark, which actually injects light, life and power in the work of a really new invention or discovery, is difficult to describe and explain. However, looking back now in the light of modern knowledge on the work of the successful pioneers in creative engineering, I am coming to some conclusions. That spark, I believe, is what might be called inventive, or creative, intuition.

XXII

A MYSTERIOUS FACULTY

SUCCESSFUL pioneering in art, science, engineering and in other branches of human activity usually includes one or both of the following factors: discovery and creation; the latter, in the technical field, may be called invention. As an example of the first we may mention the discovery of the law of gravitation by Newton, or the discovery of America by Columbus, or similar cases where the object or law existed in the material universe, but became known or explained to mankind as a result of the work of some individual. By creation, we may mean such work as a painting by Raphael or a Rachmaninoff symphony, or the steamship of Robert Fulton. According to extreme materialistic conceptions, such discoveries or creations may merely be the result of a cut and try process, repeated a sufficient number of times. The argument is familiar.

The whole universe, as well as every atom on earth, is in constant motion. While this has gone on for trillions of years in the universe and for thousands of millions of years on the earth, there have been innumerable opportunities for particles to form various combinations in matter. A happy combination in the living matter, such as an individual being who has greater strength, or better eyesight, or better intelligence, has a greater chance to survive and reproduce, and as a

result we have evolution and progress, of which we all, as well as the creative intellects of our great men, are a product.

The possibility of obtaining a higher result by chance from the accidental play of unintelligent forces can be illustrated by the case of the six monkeys. The following sentence is taken from a most interesting book, *The Mysterious Universe*, by Professor James Jeans: "It was, I think, Huxley who said that six monkeys set to strum unintelligently on typewriters for millions of millions of years, would be bound in time to write all the books in the British Museum." In line with this, Professor Jeans mentions that "if the universe goes on for long enough, every conceivable accident is likely to happen in time." As far as I understand it, the latter idea was expressed chiefly with reference to the events in the material universe with physical matter.

I believe, however, that when the evolution of life is studied, the blind play of chance can explain only part, not all of the process. Returning to the case of the six monkeys, we can figure out the number of different combinations and, therefore, the probable time necessary to obtain certain results by an accidental grouping of particles. If, instead of all books, we take only a single page of one book and, instead of six monkeys, we take six hundred trillion monkeys, or about one on each square yard of the surface of our globe, it would be necessary to keep them busy day and night for millions of millions of times longer than the total age that we can attribute to our whole planetary system for them to write that page. This being the case, we must realize the limitations of this process of chance

whenever a complicated instrument is created.

A simple mathematical analysis, by the theory of probability, demonstrates that the "monkeys" failed to write a single page because of a lack of time available in our planetary process. How could the same "monkeys," during the same time, have produced the intellects that wrote all books, composed all symphonies, and created all sciences?

There is no doubt that in many cases the creation of a new type by nature could be well explained on the basis of a cut and try method, followed by an automatic selection or elimination. There is a classic example of some motley bugs that have a colouring similar to the trees or leaves on which they live. Their development can be explained. While nature might at random produce various coloured bugs, yet birds would pick up the brightly coloured ones, and gradually the ones with protective colouring would remain and reproduce their kind. There is the giraffe, whose long neck permitted it to feed on leaves of high trees during years when similar fellows with shorter necks were perishing from hunger. There are countless other cases that can be satisfactorily explained in a similar way. There are also different cases.

Consider the faculty of eyesight. For tens, if not for hundreds of thousands of years these complicated instruments, our eyes, must have been under gradual development. For thousands of generations the new faculty was nearly useless until it became sufficiently perfected for service. It is hard to accept the development of this remarkable optical instrument, as well as several other complicated expedient mechanisms, as being the result of an accidental combination of par-

ticles that are being shuffled by blind and brainless natural forces. I believe in a different explanation, namely, that somehow, in a way that cannot be well understood in our plan of existence, the design of such a mechanism, as well as a general plan of growth, existed prior to the time for its appearance in the visible earthly process. These design patterns influenced the direction of the evolutionary process, by the development of a new mechanism or faculty which was intended to become really valuable only after thousands of generations.

The question of natural evolution was discussed here because of some analogy with the subject of this chapter, namely, the fact that progressive evolution can be regarded as a sort of continuous creative engineering work. When nature produces, after millions of years of gradual development, an eye that can see or a creature that can fly, or when a human inventor creates a photographic camera or a flying machine, in all of these cases the result must be in accord with some natural laws and must represent something that was potentially possible. In other words, before a new creature appears in the world or before a new invention is made, it may be considered as having potentially existed in what we call the future, somewhere along the line of the fourth dimension.

Intuition appears to be some ability which permits an inventor, in a way not yet explained and possibly inexplainable, to "tune in" like a radio, and to learn, somehow, some facts or laws that are not yet known, or imagine and create a mechanism or part in correct accord with natural laws not yet discovered at the time of the invention. It may be said, therefore, that the

work of a pioneer in science or technique often consists of finding a correct solution, or creating a working mechanism, based on laws that are not yet discovered.

I do not pretend to explain the nature of the process of intuitive discovery, but I can give a few examples of how it works. It may be in the form of a fact or information held in the memory for which there is no data or known foundation, but supported by a firm conviction that it is true. With reference to myself, I always had a belief, even as a small boy, that I would sometime build and fly large flying machines. Consciously, I did not pay much attention to this idea because for many years I considered it simply impossible, but subconsciously the conviction was always there. Intuition works even when one does not recognize it as such. In other cases, it works with a surprising speed and brilliance, when, in a moment, a solution of a difficult and complicated problem comes in with remarkable clarity, and so convincingly that no doubts are left as to its correctness. Quite often it is possible to select one out of a dozen sketches of proposed solutions and state positively that one is the best, when it is still not yet possible to say why. The reverse also happens once in a while, and it is possible to predict that certain solutions will not be satisfactory even when they appear to be correctly designed and calculated.

In my own experience, during the pioneering period, many decisions were made on the basis of intuition. For instance, when I got in difficulty with the directional control on the S-1, I introduced a new rudder arrangement consisting of a fixed horizontal surface with an elevator and two fins forming end-plates and supporting rudders. Only several years later was

it proved, theoretically and experimentally, to be one of the most efficient tail combinations. On many of my early planes, and particularly on the first large four-engined ship, I introduced on the basis of feeling and in spite of the structural difficulties, an unusually high aspect ratio, which means the use of a narrow and long wing. At that time I personally was not yet familiar with the theory of induced drag, and therefore had no tangible reasons for doing it. Years later, I found out that this plane with a not very efficient airfoil, large parasite resistance, and weighing 24½ pounds per horse-power, would not have been able to fly if it had had the low aspect ratio of the majority of planes of that time.

During the early pioneering days, when correct information was scarce, and several important parts, such as the tail surfaces, had to be built on the basis of a guess or unreliable data, the thought or sight of some part would repeatedly create uneasiness or worry. While some of the reinforcements that were introduced in such cases may not have been needed, yet in quite a few cases I could later, when proper data became available, find out that the part actually was insufficiently strong and sometimes even dangerous. I owe my life to one of such changes.

Intuition is not limited to any particular field of human activity. Jonathan Swift, in his *Gulliver's Travels*, written in 1726, mentions that the planet Mars has two moons. This fact was unknown when Swift wrote his novel. It was discovered a hundred and fifty-one years later, in 1877, when powerful telescopes became available. It is indeed possible to consider this a good guess. However, considering that at

the time of Swift, Jupiter and Saturn were known to possess several satellites, the correct choice of Mars out of three remaining planets, the choice of two moons instead of any other number, and finally the suggestion of a very small distance of the satellites from the planet, which also is true—all indicate intuition.

Jules Verne foresaw correctly several developments such as the electrically driven submarine, the heavier-than-air flying machine and its successful rivalry with the dirigible, and even a war in which Germans would utilize a big gun with unusual firing range to shoot at a French city. The stories, of course, include details that could be objected to from a scientific standpoint, but they were intended to be fascinating fiction and not scientific treatises. Still, I believe that the number of engineering discoveries that were correctly foreseen is far in excess of what could have been made on the basis of existing evidence or of guessing by good luck. This ability is, however, by no means general, and many individuals do not have it, and may sincerely doubt that there is any reality behind the subject of this discussion.

I believe that in the field of science many important discoveries were made with the assistance of intuitive apprehension. Great men like Aristarchus of Samos, Archimedes, Newton, and several others upon many occasions created correct theories or made true discoveries long before enough tangible evidence became available to justify their assumptions.

My father, as a scientist, was interested in and possessed a knowledge of art and literature, in addition to his speciality in medicine. He made a study of the art museums of Europe, and had in his own library good reproductions of most of the outstanding works

of art. He found that great artists, such as Leonardo da Vinci, often showed in their paintings details in accord with scientific data and discoveries which were not known in their time. I believe that several of such cases can be explained partly or entirely by intuition. What, then, is intuition? My own ideas as to its nature are only personal speculation.

In the remote past, hundreds of millions of years ago, there were some blind and deaf living creatures, such as worms or jellyfish. If they had been supplied with intelligence, but left with their only means of apprehending the world, they would have considered that any object began to exist when they could touch it. The possibility of learning something about an object until it was reached would have been unthinkable or miraculous. Millions of years went by and some active forces designed and gradually introduced new faculties, namely, hearing and seeing. Then it became possible to recognize an object far away on a road long before it was approached and touched. Given enough intelligence with this faculty, there would come the possibility of learning some general ideas about space. We now know something with reference to space; however, with reference to time we are still completely blind and enslaved. Yet mathematics and natural philosophy have begun to explain time as a fourth dimension. Therefore, the future, not as a complete event but as a framework, may already have its existence somehow and somewhere. We must not assume that this future has no real existence. Its apparent unreality may be the result of our having no organs or faculties to apprehend it. Our situation with reference to time can be compared to the position in

space of a worm for which the clucking chicken a yard away has no reality or existence. The chicken will acquire reality for the worm the moment it picks the worm up to swallow it. To be more exact, our situation, versus time, is not even that of the worm, versus space. It is still worse. The worm can move and study space on the basis of his motion, while we are solidly clamped to a certain spot of time, and are moving along an endless chain like an assembly line in the Ford factory. Various automatic machinery is standing by, gradually shaping a product by what we call the evolutionary process. All our faculties of perception and understanding are developed on the basis of our sitting blindly on the spot of the chain. Our neighbours a few yards fore or aft on the chain, which means a century fore or aft, have no real existence for us. The machine that powerfully influenced and shaped our life a while ago, and which is now left behind, is for us in the past and has ceased to exist, except as a historical memory. Another machine is standing on its place a few yards ahead, but being completely blind along the line of our motion, we know nothing about it until we reach it.

To develop these ideas further, let us imagine that on a Wednesday of some week a man finds himself in New York. Wednesday of the next week, and the city of London in England, have no real existence for him, while he can imagine that both represent really existing definite potential frames in which events may take place. He is separated from one by an interval of space of some 3,500 miles, from another by an interval of time equal to seven earthly days. Now the man in question may board a steamer, and in five to seven days reach London, and stay there during this next

Wednesday. However, before the start, his consciousness would easily accept the far-away London as an actual fact, a solid reality, in spite of its being located some 3,500 miles away, while next Wednesday is still totally deprived of any reality—it simply does not exist anywhere and in any form according to our consciousness. When the man arrives in London, New York will cease to exist for him nearly as completely as Wednesday of the past week. However, the firm reality of New York is not at all questioned by his consciousness, while the past Wednesday appears lost for ever and completely deprived of any real existence. Now, is our consciousness right in this case, and does it picture what may be called the true status of nature in this respect? Rather not, it appears that our consciousness is misleading, and that actually the past and future may have some definite existence, but certain conditions prevent us almost completely from making a contact with this reality.

This status, namely, the seeming non-existence of the past and future is the result I believe of an absence of faculties that would permit its perception. The difference that our consciousness is attributing to the reality of "frames" or "stages," that are separated from us by space or by time, is so great because there is a considerable conflict in our apprehension along the roads of space and time. Repeating the former example, while a person is in New York, London or next week Wednesday have no real existence for him. If he is hungry, a dinner served in London, or the one that will be served on Wednesday next week, are of no value to satisfy his hunger to-day. However, with reference to space, he has freedom of action—he can

stay where he is or he can go to Europe or to China, or anywhere else, at least along the surface of the earth. While he travels he can see not only the spot he passes, but usually some part of the road ahead and behind. This is true whether he walks along a road or flies a fast aeroplane. He can stop when and where he wants, and he can travel at practically any speed between walking and the several hundred miles per hour of a modern aeroplane. He sees all kinds of motion in nature, including the travels of celestial bodies. He has the wonderful ability to see. All these faculties would permit him to build himself an impression and certain understanding about space. Conditions are entirely different with respect to time; man appears to be chained completely to a given "spot" on the line of time. He "moves" along, completely unable to change the "direction" or "rate" of this motion, or to stop it. A most important new condition, or a catastrophic event, would not be noticed even a second before it actually arrived. This forces the conclusion that the future really has no existence, while in fact this is most probably a misconception created by the extreme limitation of our faculties of "seeing" in this direction.

The fact that the future already has some existence must not be taken as denying our free will. This future probably exists as a "framework," or a stage prepared for the actors, namely, ourselves, to step on to. This may be compared to a geographic framework like London, or Alaska, or the Grand Canyon. All these "frameworks" existed before we paid them a visit. When we arrive there we have freedom to act as we please. However, the surroundings or "frame-

work" will influence our actions and all the conditions of our existence. In space, however, we may make the choice where to go, and we may usually study our destination before our arrival, while in time we are moving blindly. But taking into consideration the immense importance of eyesight, not only for a multitude of particular cases but for the general understanding of the universe and some of its laws as well, we can realize what a wonderful faculty it would be to "see" along the fourth dimension. This would also permit understanding, to a considerably greater degree, the structure of the universe and its laws of operation.

Intüition appears to be an extremely faint "submicroscopic" beginning of such a faculty. Apparently it permits one at some time, in some unknown way, to make a glance in the direction along our moving "assembly line." This ability of human beings is rare, extremely primitive, and not very reliable. Possibly our position of slaves, solidly welded to a given spot on the moving line, would permanently prevent any real development of such a faculty. Beings of a higher order of existence may be in a different position with respect to the moving line and its limitations.

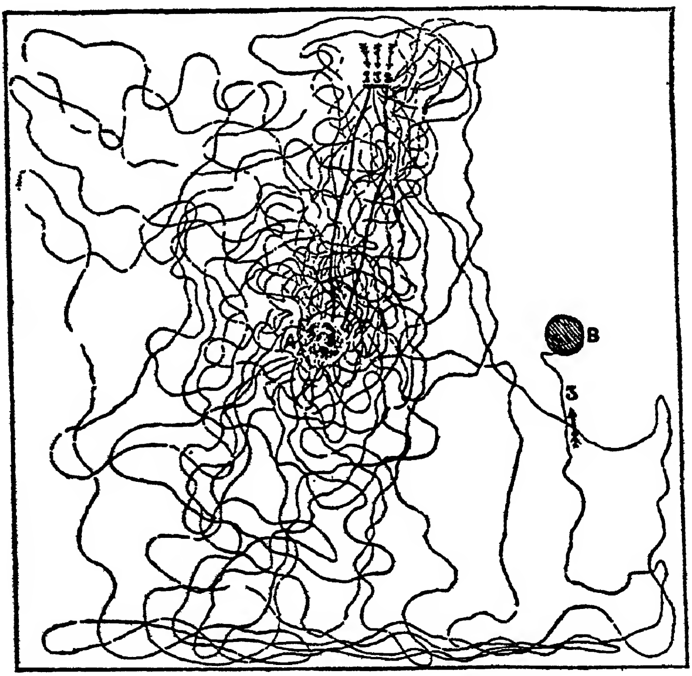
They probably can see the whole line, fore and aft; they may stand, letting the line go by, or may step in any place in the line if they so choose. The Great Designer, whose existence is, of course, independent from the moving line, can probably change even the character of its operation. But these questions are completely above and beyond our faculties of understanding and explanation.

Returning again to a modest scale of ideas and

events, we can imagine a certain period in the history of evolution when some primitive living thing started to acquire in a crude way the beginning of the faculty of seeing. Of course, with very limited intelligence, the primitive creatures used the miraculous new faculty chiefly to get something to eat, or to save themselves from being eaten. If we were to imagine them as possessing some intelligence, we could expect that the new faculty could enable them to make "discoveries" that would appear unexplainable and miraculous to their blind fellow countrymen. While the average blind creature would probably open his mouth a hundred times in every direction in order to get something in, and would get it about in proportion to the theory of probabilities, yet the next fellow, using a little eyesight, would make an incomparably better number of good guesses simply because he used a higher faculty.

This idea can further be demonstrated by a picture resulting from an experiment made by the scientist, John Lebbock, with ants, and described in his book, *Ants, Bees and Wasps.* This picture was reproduced in the book, *The General Psychology,* by my father, Professor I. A. Sikorsky. The experiment consisted of the following: a few larvae were placed on top of a small piece of pencil which was stuck in the ground. The two lines connecting the ant hill entrance in 132, with the pencil in A, represent the roads along which the ants were carrying the larvae back home from the pencil. While the ants were inside, the observer took the pencil from point A and placed it at point B. The ant came out but could not locate the pencil in the old place. However, by smell

it could feel that the larvae were still somewhere around and, while trying to find them by smell, the ant covered considerable distance which is represented by the thin white line 3-3, until finally it located the pencil with the larvae at point B, a few inches away. If, instead of smelling, the ant had used eyesight, it would immediately have located the pencil and would



have saved considerable energy and time in running around.

The use of a higher faculty, in this case eyesight instead of smell, would have permitted a short cut in obtaining the same results. This appears to illustrate discovery by intuition, as compared to the working out of the solution by ordinary methods and faculties.

In line with this and with reference to mankind, there is no good reason to maintain that the existing faculties of apprehension and understanding are the only possible ones. It is true that it is extremely difficult to imagine, and still more so to describe, a new faculty if it is of a higher order. To make this clear, let us imagine some intelligent being that possessed only the three lower faculties—touch, taste, smell—and never learned about any others. How extremely difficult, not to say impossible, would it be for such a person to imagine what hearing or eyesight is, if there was no one to give any ideas about it. Now this is our present situation with respect to any possible faculty of a higher order.

The phenomenon of discovery of unknown facts by intuition, however, appears to be a reality, and while the background and the true nature of it cannot be properly understood and explained, yet my personal feeling is that intuition represents not an over-development of some of the existing faculties of apprehension and understanding, but rather an extremely primitive and barely noticeable beginning of a new faculty of a higher order, just as radio communication is not an improved or over-developed pony express, but is a totally new phenomena based on natural forces of a superior order. Intuition, if and when developed, would be superior to eyesight in a way in which this latter is superior to touching or smelling. As it is in the case of some other abilities, the new faculty is very differently pronounced in various individuals. It can be expanded and developed by training.

The idea of the connection between the intuitive abilities and the element of the fourth dimension can

well be considered speculative and arbitrary. But every successful invention and discovery usually represents a work for the future; it is in fact the creation of the future. When Thomas Edison planned to flood his country with electric light, or when Henry Ford was contemplating putting it on wheels, they both succeeded because they were able to foresee correctly the future with its requirements and to arrange and direct their efforts accordingly.

Another manifestation of the " mysterious faculty " is the confidence which it creates somehow in the mind of the pioneer that the object of his efforts not only is possible but will actually be fulfilled—in other words, that it exists in the future. Such confidence is often in disaccord with any tangible contemporary proof; in fact, it is frequently contrary to the accepted scientific evidence, as well as general opinion, and is therefore subject to criticism and ridicule. This confidence is created by some kind of conjectural knowledge of the future.

An illustration of this idea can be taken from the history of flying. There is not the slightest doubt that mankind was thinking and dreaming about flying for thousands of years. Yet from what we know, there were almost no practical attempts made until the end of the eighteenth century, and during the whole nineteenth century, when several practical men decided, for no tangible reason, that flying was possible and would soon be brought about; therefore, it was worth while to work in that direction. It is often argued that inventions depend for their feasibility on the whole scientific and industrial development of the epoch and, therefore, the possibilities of a new creation in the

engineering field depend on several factors such as a variety of scientific data, materials and parts, skilled mechanics and machines for construction, and so forth. In many cases this is true. To create an automobile, for example, one must have high grade steel, ball bearings, spark plugs, magnetos, tyres, springs and many other materials and mechanisms that are not made or "invented" by the individual designer, but which must be available at the place and time to make the work possible. A complete set of blueprints and specifications of the simplest automobile would be useless to the best technician or craftsman of ancient Rome or Greece, or even in the middle ages in Europe, because a whole industry supplying high grade steel, bronze and tyres, as well as trained mechanics of different types, would be needed.

While the same is true with reference to the aeroplane, yet at least two types of aircraft could have been created and flown thousands of years ago. They are the glider, or soarer, and the hot air balloon. Even in ancient Egypt there were good woodworkers entirely capable of building a glider, if given proper instructions. Various kinds of structural wood, as well as light tissues, and good varnishes and glues, were available in all ancient civilizations; and sportsman-like youth, particularly in ancient Greece and Rome, would have been perfectly willing and able to learn how to sail them. The design of a glider represents a problem different from other phases of engineering. In present day aircraft of this type various aeronautical engineering facts, as well as standard aircraft materials are used, but all this is not essential, and it would have been entirely possible to produce a glider out of materials and parts

that were available in ancient times. As for aerodynamic data for the design, I know two outstanding aeronautical engineers, with fine intuitive abilities, who developed excellent air-foil sections, and main body shapes, using small glider models weighing about one pound. Launching these models, and comparing the character and distance of the glide from a given altitude, they succeeded in developing some outstanding and efficient air-foil sections. Such procedure would have been just as feasible at the time of the construction of the Pyramids.

Before the advent of the power age, or before the nineteenth century, the glider would have been a wonderful instrument for peace and war. The problem of flying always had a great attraction, and if it had been thought possible the problem would have been attacked persistently, and solved hundreds or even thousands of years ago. When finally the flying machine was created, this great achievement was brought about by a handful of men, working mostly with their own hands, with extremely modest equipment and expenditures. Various students of aeronautics and scientists of the second half of the nineteenth century systematically paved the way by making flying models and collecting information; gallant attempts with creditable results were made between 1890 and 1900 by Ader, Hiram Maxim, and a few others. The first tangible results with gliders were achieved by Otto Lilienthal, and, finally, the whole brief history of earnest attempts was crowned by the great and brilliant achievement of the Wright brothers.

While the power-driven aeroplane could not have been produced much earlier than the twentieth century

because of the dependence on modern industry, yet the glider was accomplished by Otto Lilienthal, the Wrights and others, almost without a prior art, or engineering information, working under conditions that could have been duplicated in ancient times. Why, then, was it not done by men like Leonardo da Vinci in the fifteenth century, or by Archimedes in the third century B.C.?

This is my explanation. The conquest of the air, with its profoundly important influence on the history of humanity will remain one of the outstanding facts of the twentieth century. Intuitively several of the more developed and sensitive men of the time were influenced to work in this direction. During the fifty years preceding the advent of flying, there appeared a marked anticipation of the flying machine. The feeling became real and active, even while tangible proofs were absent.

But why did intuition, which apparently said little during thousands of years, start to talk extensively and convincingly during the fifty years that preceded flying? There may be a limit to the range of the intuitive faculty or possibly the future patterns assume a definite background only as they are approached by the "procession," or finally, recollecting that nearly every kind of motion we know in the universe is along curved and not straight lines, we can postulate the motion along a curve even to the element of time. If this is the case, intuition may be limited by conditions similar to our eyesight, which cannot see a ship beyond the horizon.

These considerations are not in disaccord with the fact that important scientific discoveries, such as the idea of the atom or the central position of the sun in

the planetary system, and many others, were proposed by the scientist-philosophers of ancient time, nearly 2,000 years before the discoveries were actually made and reliably proved. The reason is that such scientific achievements are of the category of discoveries, not creations. In other words, they are discoveries of realities that are permanently in existence in the universe. While the creation of the flying machine was a local event, it depended on the development of mankind and apparently represented a part of the stage of the twentieth century.

Finally, we must distinguish intuition from supernatural phenomena such as revelation or inspiration which, according to religious belief, are messages received from Living Intelligence of higher order. This is not the case with inventive intuition. The term "mysterious faculty" was used in order to emphasize the fact that it is unknown and unexplained, but it is a natural faculty, which brings us in contact with realities of the material world. How it is projected, I do not know, but I, for one, do not question its reality. However, the explanations of its nature and functioning that have been presented in this chapter must not be taken as anything more than personal guesses and speculation. Material evidence or tangible proofs are not available to confirm these ideas.

XXIII

IDEAS ABOUT THE FUTURE OF FLYING

TWENTY-SIX years ago, the summer of 1913, the first large aeroplane with four engines was being flown over Petrograd. This ship, with an enclosed cabin for eight passengers and a gross weight of some four and a half tons, was much larger and heavier than any other plane of that time, and was generally considered too big and heavy to fly. In this quarter of a century aviation has made greater advances than any other method of travel within this short period. All continents are now covered by a network of air-lines. All oceans are crossed by flying service, and it is now possible to fly along established air-lines from any of the large cities of America to Europe, Asia, Africa and Australia; in other words, to any one of the continents.

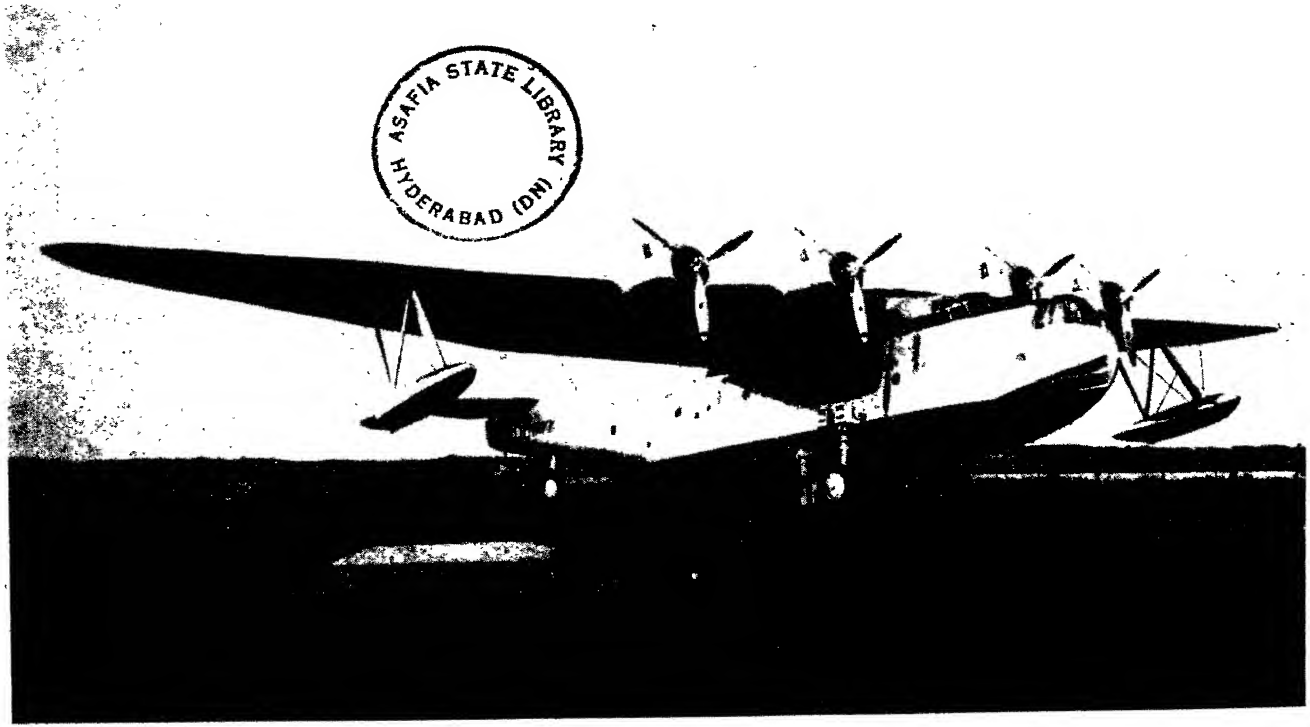
The engineering achievements reduced to facts and figures are also quite impressive. Let us analyse, for instance, the record of speed of 440·68 miles per hour, established by Francesco Agello in Italy in 1934. Starting from the latitude of London on some morning in the summer and travelling with such speed true west all the time, one could go round the world and be back in London before sunset without losing sight of the sun. While the elapsed time would be a little over thirty-five hours, yet the sun would hardly be able to

overtake the plane and it would be possible to circumnavigate the globe in daylight without seeing a single sunset.

If we were to drop a heavy weight from the top of the Empire State Building, which is about 1,200 feet high, disregarding the resistance of the air, the load would strike the pavement of Fifth Avenue with a speed less than one-half of the 441 miles of the plane. In order to reach this speed, it would be necessary again, disregarding the air resistance, to drop the weight from a height about five times greater, namely, from more than 6,400 feet. The speed of this plane is about one-half of the velocity of an ordinary revolver bullet.

As for the greatest altitude, the present World Record is 72,394 feet. It was established by Captain G. A. Anderson and Captain A. W. Stevens of the United States Army Air Corps, in a stratosphere balloon. While at the maximum altitude, these aeronauts had about ninety-five per cent of the mass of the atmosphere already below them and only a tiny five per cent of the rarefied air still separated them from the mysterious depths of interplanetary space. From this height they could observe and photograph the curvature of the earth.

Analysing these results, as well as a great many others, and recognizing the considerable progress and the numerous achievements made in all branches of the aircraft science, industry and flight operation, we can appreciate that the last twenty-five years were not spent in vain. It may now be interesting to glance ahead and to discuss what can be expected in aviation during the next quarter of a century.



The S-44 Sikorsky Patrol Bomber, powered with four Pratt & Whitney 1,050 h.p. engines. This ship, when completed in 1937, was the largest flying boat of the U.S. Navy

An artist's sketch of the proposed Sikorsky 100-ton Trans-oceanic Flying Clipper

Twenty-six years ago the four-and-a-half ton S-21 was considered too big to be able to fly, or at least to be practical. At present there are many successful aeroplanes between five and ten times this size. The Pan-American Airways recently made a request for a study, and eventual construction, of a flying Clipper that would carry a hundred passengers and a crew of sixteen, with good sleeping and dining-room accommodations, and a flying range of 5,000 miles at a speed of not less than 200 miles per hour.

I believe that with our present knowledge, materials and power units, such an aircraft is not only possible, but will be practical and will mark the next important step in the development of air travel. In order to fulfil these requirements, a plane with a gross weight of 85 to 100 tons would be necessary, with engines totalling 10,000 or more brake horse-power, and a wing span well in excess of 200 feet.

While such a plane would be substantially larger than any in existence in 1938, yet, generally speaking, this weight, size and power is not at all extravagant compared to other objects constructed by man. For instance, the largest steamship, dirigible and the tallest building, all have their main dimension of the order of 1,000 feet. If a plane with such span were to be built, it could be expected to weigh several thousand tons and to require close to half a million brake horse-power. I do not think that there is any positive evidence to indicate that in the more remote future even such a plane would be impossible from a technical standpoint. I think, however, that practical considerations will most probably never require planes of such size.

The size of aircraft in the future will probably be

dictated, not by engineering limitations, but by economic factors and traffic requirements. Travel by air is essentially a fast method of communication which requires frequent departures in order to be really useful. It is not unreasonable for a passenger or a letter to wait three days for the departure of a steamer which would then take about one week to cross the Atlantic. If a passenger or a letter were to wait for three days and cross the ocean in eighteen hours in a plane, the long waiting would defeat, or at least considerably reduce, the value of air service. To make the latter efficient and valuable, daily departures across the oceans, and still more frequent schedules across the continent, are necessary.

Another factor that will influence the size of aeroplanes is their operating efficiency in carrying passengers. If, for instance, we compare a trans-oceanic steamer carrying 2,500 passengers with air-liners carrying 100, we may at first think that twenty-five planes are needed to do the service of one steamer. Actually, however, the steamer will make one trip during a week, while the planes would make at least five trips each, therefore, five air-liners carrying 100 passengers each could replace a large steamer. Therefore, it appears that the speed and efficiency of the air-liner as a passenger-carrier would place a practical limitation on size long before the engineering possibilities might be exhausted.

All this being the case, it does not seem necessary to renew the old argument about the technical limitations of the size of aircraft of the future. I personally believe that flying boats of 500 or even 1,000 tons, carrying several thousand passengers, could be suc-

cessfully designed and built in the reasonably near future. However, for reasons that were discussed above, a large number of ships, of 100 to 250 tons, with frequent departures, will render better service, and will probably remain the flagships of the intercontinental flying fleet during the next twenty-five years. The land transports probably will not reach this tonnage, because the sizes of airports, difficulties connected with the use of too big landing gears, and, finally, the advantages of frequent schedules, will place a limitation on the practical size of land transports of between 50 and 100 tons.

The 100-ton trans-oceanic flying boat is, however, the prospect of the immediate future. Within a few years we will travel to Europe on ships that will cross the Atlantic in less than twenty hours. The flight will be luxurious and pleasant. There will be some fifty comfortable state-rooms, a large dining-salon that may be used for dancing or games in the evening, promenade decks, smoking lounges, a library, comfortable living quarters for the crew and, in general, most of the accommodations found on a first-class yacht, except the swimming pool.

Few people, however, outside of the men directly connected with aeronautics realize that, beyond the obviously important engineering problems that cover the design of such an aircraft and its power plant, there are other new complexities connected with the equipment of these flying hotels of the immediate future. There is the problem of heating while the metal body of the flying ship is cooled by the 200 mile wind at -60 degrees Fahrenheit of the substratosphere. There is the electric power plant to supply the energy

for a multitude of various devices and mechanisms, as well as to light the ship. There is the air conditioning and the supercharging of the cabin necessary to provide comfortable conditions on board when flying at 25,000 feet, where the air pressure is only one-third what it is at sea-level. There is the vast and important problem of sound-proofing. There is a long list of auxiliary mechanisms, flying and marine equipment and instruments.

But all this is now routine engineering work. It will be done in the near future and the new super-Clipper ships will bring more luxury and regularity in the trans-oceanic service. Europe in less than twenty hours, Asia or Australia on the second day, round trip cruises of three to four days from New York to the North Pole or to the Amazon River jungles, may be expected to be in operation during the first half of the next twenty-five years.

Speed? As was mentioned before, the present 1938 World Record is 440·62 miles per hour. Twenty-five years ago it was 126 miles per hour, or less than one-third of the present figure. Would this indicate that within the next twenty-five years another such step would be accomplished, and the speed mark raised beyond 1,000 miles per hour? On the basis of our present knowledge, it appears very improbable that this will be the case.

It has been demonstrated within recent years that at a speed of approximately 500 miles per hour, an important change takes place in the flow of air around a moving wing and body. While the really critical point appears to be closer to the velocity of sound, which is about 760 miles per hour at sea-level, yet

adverse effects in the streamline flow and a considerable increase in the power necessary to move the aircraft through the air, appear when the speed reaches or approaches 500 miles an hour. This places a serious handicap on a further increase in speed.

Another difficulty is connected with the characteristics of the propeller. While its thin metal blade may travel through the air with good efficiency up to the speed of nearly 700 miles an hour, a further increase would involve pronounced loss of efficiency. It must be remembered that the propeller tip always travels faster than the plane because of the fact that the propeller tip moves in an advancing spiral. So there is another limitation of speed in the fact that the propeller efficiency is bound to fall off quickly if the propeller blades were to exceed the above-mentioned speed of 700 miles an hour. This being the case, to obtain a speed much in excess of 500 miles an hour for the plane, it would probably be necessary, in addition to a new study of wings and other parts, to devise a new type of propulsive mechanism and to produce a new power plant delivering considerably more energy for a given weight and size.

Although the modern aeronautical engine is being continually improved, yet it can hardly be expected that a great reduction in weight and in the volume per unit of power, can be accomplished unless a new and more efficient principle of producing mechanical energy is discovered. These factors appear to place a narrow limit on the future increase of speed and, while progressive design engineering will probably enable aeroplanes to exceed the present records, yet no great improvement in maximum speed should be expected

during the next twenty-five years, unless new methods of generating power are discovered.

However, the 200 miles an hour of operating speed which has been approached and will soon be exceeded by regular air transport is, to my mind, entirely sufficient to justify travelling by air. This velocity is roughly eight times greater than that of a steamship and about four times greater than the best railway. In the future we will see a further increase in speed, but whether it will approach the limits that were discussed above or will stay between two and three hundred miles per hour, will depend on practical decisions based on the economics of travel and other factors.

Undoubtedly, the present World Record of 51,364 feet of altitude for the aeroplane, will be substantially exceeded, but we may expect that somewhere between 75,000 and 100,000 feet, we may reach a limit above which the aeroplane driven by internal combustion engines and propellers will not be able to rise. The stratosphere air-liner, travelling between 25,000 and 40,000 feet, with an enclosed supercharged cabin will, of course, make its appearance in the very immediate future. In this case again, the factors of economics and convenience of operation will determine whether or not a large part of a passenger traffic will travel at this very high altitude. The advantages of stratosphere flying, namely a certain gain in speed and the ability to fly above weather disturbances, are very interesting, but the difficulties and operating complications are not yet known and may prove to be greater than the advantages expected. If this proves to be the case, a substantial part of the air travel of the future may

remain at lower altitudes and in the substratosphere, but a certain amount of transport flying will most probably be in the stratosphere.

As for the small air flivver, I believe that its development will be very gradual. The creation of new types of light, inexpensive aeroplanes with simplified controls, particularly amphibians, will take place gradually in line with the development of airports, various auxiliary services and general air-mindedness. Safety, low cost and excellent take-off and landing characteristics from small fields are now receiving serious attention from designers and will eventually contribute greatly to the success of the private air flivver. A further expansion of private flying may be expected later when a good, practical, direct-lift aircraft, probably of the helicopter type is developed. If one could store the machine in one's backyard and lift it from there or from aircraft parking platforms that will in the future cover entire blocks in the hearts of modern cities, a vast new field would open for the use of aircraft by the private flier. An aircraft that would land with little or no forward speed would eliminate the difficulties and troubles connected with fog and darkness, which remain serious for the private pilot-owner who cannot use the radio, equipment and knowledge of the professional navigator of a large air transport. When this development progresses far enough, we will see hundreds of thousands, possibly millions, of privately owned machines in use. This, however, is not around the corner and may take another decade or two to take place.

In the class of small flying machines, we can expect surprising novelties with reference to the general

design. Various new combinations of wings, flaps, slots, jets for propulsion or for the control of flow around the air-foils, new types of tails or no tails at all, will appear in the near future. Various types of aircraft with rotary wings and helicopters, with one or with several lifting-screws, will also make their appearance. The latter group in particular will include some strange-looking machines, similar to huge butterflies when in action.

The gliders and soarers will remain popular and will be used for sport, training and in some cases for scientific research. The power glider will soon be seen also and, besides sport and training, will be used for very economical travel. It is probable that the gliders of the future will not look much different from the present ones and will remain generally similar to the big soaring birds.

The huge air-liners of the future, that will carry hundreds of passengers and heavy loads for considerable distances at high speed, will probably resemble in general appearance our present large planes. Not long ago the air-liner of the future was visualized as a huge flying wing, with engines, all passenger and control cabins and so forth, situated inside. Such an aircraft is possible and may be advantageous in cases where cargo and only a few passengers are carried and cabin supercharging is not essential. In the case of a normal air-liner, with an efficient wing of proper shape and thickness, there would not be enough head-room inside the wing in a plane of as much as 200,000 pounds. Even in a ship of 500,000 pounds, with proper wings, the room would be several times smaller than what is needed to accommodate properly the number of

passengers that the lifting capacity would enable the wing to carry.

So it appears probable that the large, palatial air-liner of the future will still consist of a proportionately narrow wing, like that of an albatross, a streamlined body, closely resembling the shape of a dirigible, and a small, possibly partly retractable, tail. From 100 tons and up, land transports and flying boats will look very similar. Engines, numerous other mechanisms, fuel, cargo, part of the living quarters and promenade decks, will most probably be located inside the wing. The major part of the state-rooms, dining salons and other rooms, will remain in the main body or boat hull. Only this latter part would be supercharged and, therefore, when flying at high altitude, it will not be possible for passengers to remain in the wing compartment. Members of the crew will be able to visit the wing compartments for the inspection of engines and other mechanisms. While doing this they will use special pressure suits, or oxygen, for breathing. To pass into the wing from the supercharged body, they will have to enter a small pressure chamber, close behind them an air-tight door, gradually decrease the pressure, and only then open the door leading to the non-supercharged wing corridors.

Looking beyond twenty-five years, we can visualize these huge flying ships with eventually three or four decks, hundreds of state-rooms, long promenade and observation galleries, dining salons, smoking and dancing rooms, elevators to communicate between the lower and upper decks, various rooms for recreation, games and sport. While in flight they will look like a conventional aircraft, and only their remarkably

steady and seemingly slow motion will disclose to the experienced eye their huge size and weight. After landing, and at close range, these ships will be very impressive with their huge and powerful wings stretched out over the pier like a gigantic roof and their large, streamlined bodies with several long rows of port-holes.

There are many other interesting questions connected with modern and future aeronautics which the programme and size of this book will hardly permit me to discuss. It seems, however, appropriate to mention a few general ideas about transportation and its dependence on the characteristics of the sources of motive power available, because the most interesting possible developments will be connected with that problem.

Before the nineteenth century, the main sources of energy in use for transportation purposes were the muscular power of man and domestic animals and the force of the wind. In all these cases the weight of the power unit was usually from several hundred to a thousand or more pounds per horse-power. Modern aviation engines have a weight of 1 to 1½ pounds per horse-power. This astonishing decrease in weight, or, in other words, the concentration of several hundred times greater power in the same volume and weight, made possible mechanical flight, as well as the achievement of remarkable speeds on water and on the ground.

This concentration of power will remain among the outstanding achievements of engineering. In 1884, the Frenchmen, Renard and Krebs, assisted by the designer of the early electric generators, Gramme,

produced for their dirigible a power unit that had a weight of over 110 pounds per horse-power. During the following forty years the weight per horse-power was reduced about one hundred times. This miraculous and unprecedented engineering achievement made possible the various records of modern aviation. However, in order to exceed twice or three times the present top speed of 441 miles per hour, or the 51,000 feet of altitude, now reached by aeroplanes, a further and great concentration of power will be necessary.

Now can it be expected that another large step in this direction will be made and engines developing, say, 100 h.p. per pound of weight may become available? The answer to this question appears to be decidedly negative as long as the combustion of fuel remains the source of energy. In addition to the great difficulty of a substantial further reduction in the structural weight of the engines, there is a more important factor, namely the weight of the fuel. For instance, on our S-42 Clipper the weight of the four engines, which deliver 3,000 h.p., is approximately 4,270 pounds, while the 2,700 gallons of fuel taken on board for a 3,000 mile flight, have a weight of over 16,000 pounds.

This being the case, it can be seen that, except for short distances, it is the fuel which represents the major item of weight. To reduce this, it would be necessary either to increase the efficiency of our engines by utilizing a higher proportion of the energy of the fuel, or to find another kind of fuel that would store much more energy per unit of weight. With reference to the first question, the efficiency of the modern engine

that can in some cases deliver 2½ h.p. for one hour, using one pound of fuel, is already surprisingly high. I believe that further improvements may gradually raise this figure, but it will hardly be possible to exceed in actual service, 3 h.p. an hour per pound of petrol or fuel oil which at present seem to be the best and most compact containers of energy that are known. Dynamite, or some other highly explosive substance, has often been proposed as a source of motive power. This does not seem to be promising because, contrary to the general belief, a pound of petrol or kerosene contains several times more stored energy than a pound of dynamite or powder. The reason for this is that, in the case of petrol, the oxygen necessary for combustion is taken from outside. Therefore, out of the two chemicals needed for the operation of the engines on an S-42 for a 3,000 mile flight, only eight tons of petrol are taken on board, while the rest, namely, the 110 tons of air containing about twenty-two and a half tons of oxygen, are taken in from the atmosphere. But in explosives, all chemicals must be in the plane from the beginning, and therefore the amount of energy per unit of weight is several times less than in petrol.

Among the various kinds of possible fuels, it is only hydrogen which contains for the same weight over two and a half times more energy than petrol or any other known type of combustible. Hydrogen cannot be used at the present time, because in the state of a gas it needs considerable volume; while to use it compressed necessitates very heavy containers. Finally, in liquid state the boiling temperature is so low (-423 degrees Fahrenheit), that it is too difficult to handle. If, however, methods of economic and practical hand-

ling and storage of liquid hydrogen were to be developed, it might become an ideal universal type of fuel for aircraft. It would raise considerably and at once the performance of any type of aircraft and particularly the range of long distance ships. It would make possible a non-stop flight, without refuelling, round the world along the Equator. It would immediately increase the ranges of bombing planes more than two and a half times with the same military loads or increase considerably the military loads carried for the same distance.

In view of all this, the development of liquid hydrogen, in forms that would permit practical utilization and storage, would represent a very interesting problem for the chemists of the future. If, and when, the problem is successfully solved, it will result in encouraging a new industry for the making of liquid hydrogen, which will require a large amount of energy for production. There are still hundreds of millions of unutilized horse-power in the waterfalls in various parts of the world and also there is the energy of the tides. Finally, there is the heat of the sun, which delivers more than 3,500 h.p. of energy per acre in tropical lands. There are thousands of millions of acres of non-usable desert land, which in case of real need could be used for the harvesting of solar energy. This, of course, is not a prospect of the near future and may occur only if more energy is needed for general uses outside of aeronautics. Even the use of liquid hydrogen, however, would not push speed much beyond the figures that were mentioned before.

It would seem, therefore, that in the light of our present ideas of aeronautical and general engineering,

nature has placed a speed limit of some 500 to 600 miles an hour on air traffic, at least for the time being. While extreme engineering efforts and ability may possibly improve this figure slightly, yet a really great advance, such as 1,000 miles an hour, cannot be expected for a long period until a new era will arrive in the technique of power production. While I believe that this will come eventually, it is difficult to predict whether it will take decades or centuries of scientific and engineering research work to reach this next important stage.

In concluding this discussion of some of the future developments in aeronautics, I would like to mention briefly the probable character of the next era in power engineering and its possible influence on some of the advanced types of aircraft. We must look far beyond the next twenty-five years and, to visualize these future possibilities, we must first briefly summarize past experience and draw some conclusions on a basis of analogies.

For several thousand years, until the nineteenth century A.D., transportation was derived from sources of power that weighed roughly a thousand pounds per horse-power and, accordingly, permitted an operating speed of about ten to twenty miles per hour.

At the present time an operating speed of roughly ten times greater in the fastest vehicles of transportation is obtained by the use of a different source of power, which permits the delivery of several hundred times more energy within a given volume and weight of a power unit. The progress in concentrating greater power in a unit of comparable weight and size was excellent during the last half of a century. While

some further development is still possible, yet natural limitations of the process of securing energy from combustion are well in sight and radical further improvements cannot be expected. Valuable practical gains could be obtained from the use of liquid hydrogen as a fuel, but this will not be sufficient to exceed greatly the limitations in speed and altitude that were mentioned before.

These limitations will be removed if, and when, a new great step is made in further concentration of the source of energy and when power plants developing for several hours hundreds, or even thousands of horse-power per pound of total weight become available. This appears to be out of the question by means that are now used for generating power. If and when, however, mankind learns how to release and control sub-atomic energy, the creation of such power units may become possible.

One gallon or six pounds of fuel would carry our twenty-ton flying Clipper a little more than one mile on the basis of the energy of cumbustion. The same six pounds of some proper substance would carry the Clipper at least forty times round the world if only part of the sub-atomic energy were utilized.

There seems to be little doubt that this atomic energy is a reality. It is most probable that our Sun, and the other stars which are the power stations of the universe, maintain their enormous output of light and heat by using the sub-atomic energy of their gradually disintegrating mass. We do not know how to release it in practical quantities, and we do not even know for sure if this can be done within the conditions of temperatures and pressures that can be created by man.

Nevertheless it is possible that eventually the combined efforts of physics and chemistry, after centuries of work, will find ways of releasing and controlling sub-atomic energy. The immense importance of this discovery could probably be compared only to one other, made perhaps a million or even more years ago, by some unknown super-genius, namely, the discovery of the use of fire. I believe that this invention remains until now the greatest ever made by a human being. It may be considered among the landmarks that record the beginning of the era of man.

If, and when, sub-atomic energy is released and conquered, it will place at the disposal of man sources of amazing power. Intelligently and properly utilized, it will permit miraculous accomplishments that will have a greater influence on human life than any other invention except the discovery of the use of fire. With a nearly unlimited amount of light, heat and power at his disposal, the scientist of the future will be able to transform night into day, winter into summer on the space of the largest modern city. The most wonderful other engineering achievements will become possible, but the brilliant era may easily be brought to an untimely, tragic end if intelligence and good-will among men has not progressed by that time substantially beyond the present level.

In aviation we could expect sweeping changes. Strange-looking aircraft of novel design, similar to large gun shells with elongated cylindrical bodies, very sharp fronts and blunt rear ends, will make their appearance. Driven and controlled by powerful jets, these meteoric craft will reach the speed of several thousand miles per hour in the upper stratosphere.

The aerodynamics of the barbarous twentieth century will be of little assistance in the design of these machines. Ballistics, and the study of rockets, will be helpful at the beginning until new, supersonic aerodynamics, dealing with velocities beyond that of sound, are developed.

New types of super-stratosphere craft will eventually reach Europe in three quarters of an hour after leaving New York and will make possible a two to three hour trip round the world. The use of magic, sub-atomic energy may even open the way to a far more ambitious attempt—the space rocket. With further scientific discoveries and such a source of energy at his disposal, a pioneer of the future may succeed some day in breaking the chains of gravitation that have kept man a prisoner on this earth since the beginning of the race, and start on a trip across the mysterious and unknown depths of interplanetary space towards the discovery of new worlds.

Is all this possible, or is it only plain fiction? This question cannot be answered on the basis of our present knowledge. As for beliefs and guesses, anyone may have his own. If, however, during the next few hundred years science and industry develop at the same rate as during the last century, such discoveries may well be expected. I, personally, believe that this will come, unless the march of scientific and industrial progress is interrupted by some catastrophic event or by the destructive foolishness of man himself.

XXIV

CONCLUSION

TO complete this book a few more ideas, mostly of a personal character, ought to be developed. The work connected with the Winged-S, which was the principal subject of discussion, has been in progress now for almost thirty years. It was well under way twenty-six years ago when, in the spring of 1913, the author was flight-testing the first successful large aeroplane powered by four engines. It is a long period for the professional activity of an individual and under the best circumstances it can hardly be expected to extend in the future even half as much more. This is the maximum, while the minimum may be considerably shorter. A change in the character of personal activities may be brought about by various causes, the most important of them being the possible necessity of making a long distance flight for which one-way tickets are received free of charge, while a return reservation cannot be secured at any price.

While days rush by in the restless haste of modern industrial activity and the latest type of plane urgently designed and quickly produced is obsolete almost before the first flight and is already too slow no matter how fast it is, there is not much time to think about the fundamental value of this work. However, some-

times in the quietness of the night, in line with the writing of this review of a life's work, it is interesting to analyse some of the major questions and to evaluate somewhat the results of the work of one's life.

Indeed, the progress of aviation, towards which this work was a modest individual contribution, was remarkable during this short period of one generation. Enormous speeds and altitudes were reached, predicted limitations in range and useful load repeatedly exceeded, all continents and finally oceans were covered by a network of air-lines. It would be easy to continue the list of outstanding achievements, but it would be much more difficult to prove conclusively the intrinsic value of these accomplishments; in other words, to satisfy oneself that all this contributed towards making the world better and men happier.

Even this question, however, permits a reasonable analysis and answer which with reference to the case under discussion may be expressed as follows. The work done may be compared to a few grains of sand and cement in a block which, together with a multitude of other blocks, is used to erect a huge and beautiful palace. By the block we understand aviation, while the building is our material progress. As for happiness, or truth, they are mainly connected with human nature and only indirectly with material achievement. Inside the palace we may be happy or sorrowful; we may look towards the highest ideal and perfection or we may commit a foolish or criminal act and, in the latter case, should not blame the building. These few words may be appropriate when we recall some of the criticism of modern civilization.

In its substance this question must perhaps be

approached in a different way. Laying aside a sophisticated discussion, but meanwhile accepting fully the various faults and sins of material civilization, we can realize that the advantages and merits are far in excess of its deficiencies.

The adventures of Tarzan look grand on the screen, but, as a reality, such a life would quickly become quite intolerable. Taking purposely only a few very minor details of it, if we were to imagine ourselves to be deprived of soap, insect powder, anæsthetics in the dentist's chair, the drug store, and just a few similar products of civilization, life would become very unpleasant. The major factors were purposely omitted from discussion. Their analysis would, of course, prove the case in a much more serious and convincing way, but one which would be beyond the modest subject of this book.

Not at all generally, yet sometimes, the primitive life of the past may have had its simple attractiveness. It is possible that in many cases people had less worry and may have been happier than we are now. But this status cannot be restored. A child may be charming in its cradle, but a grown-up man who would imitate it would be ridiculous and unattractive. The same is apparently true with the progress of humanity, of which material civilization represents a certain visible part.

As for the numerous, and sometimes alarming, dark spots of modern life, they exist in spite, and not because of, progressive engineering work. During my thirty years of active life, I had the good, as well as the bad, luck to learn and experience more important events than an average man would apprehend in a hundred years. I feel convinced that if the leaders of modern social, political and philosophical thought would do

their job one-half as well as the average research engineer, the present world would be a much safer and happier place in which to live.

It must be admitted, however, that to a certain extent technical progress also contributed indirectly to the failures and disappointments of our time. The trouble is, that with the rapid development of our industry, transportation, communication, interchange of materials, products and ideas, the political and economical situation became so much more complex that it is now much farther from the understanding of the average man than it was before. If the degree and percentage of correct understanding of facts could be properly measured and expressed, I have no doubt that a simple farmer of the time of George Washington would be found to know and understand correctly a greater part of the realities and facts of the administrative and economical operation of his country than would be the vast majority of the population of all countries at the present time. The extreme complication of modern national and international life and economics is so misleading that masses of men cannot understand how little they know about the realities and facts.

I would never take the initiative in using the uncomplimentary word "masses" with reference to men, if it were not already an established modern expression. Because by "masses" we mean large quantities of some substance like snow, or sand, or pig iron, something which is essentially inert, soulless and brainless. The troubles of modern life are numerous and serious. The general restlessness, strikes, racketeering and revolutions are not a compliment to the intelligence of man-

kind. All this happens in spite of, and not because of, scientific and engineering progress, and if the " masses " of mankind, and many of their present leaders, would acquire only a part of the respect for truth and realities which an engineer takes for granted, the general outlook would be very much better.

An engineer who, together with millions of other men working in the industries and in transport, as well as hundreds of millions of men in various other branches of creative and productive work, is serving material progress, can be satisfied with his activity. If he does his job well he may know that he has contributed a certain minor fraction of energy that is needed to make things a little better, or at least less bad, whatever the case may be, depending on the major factors that are not under his control. The value of any such work must not be over-estimated and usually the production of a record-breaking aeroplane, that would fill for a day or two the pages of papers, is not a greater achievement than the creation of a good fruit orchard, or a farm, or any of a multitude of other achievements. They are equally needed, as part of some great general picture, the value and significance of which we cannot properly understand for many reasons, just as a tiny, coloured stone, placed by an artist in a huge mosaic picture could not see and understand its significance even if it had eyes and intellect. Possibly the long-distance flight that was mentioned above will furnish the perspective of space and time that will enable us to understand its meaning.

But the results of the work of a design and development engineer give sometimes a real satisfaction. True, it is not greater, as well as not more deserved, than the

happy satisfaction of the sower who sees the results of his work and the object of his hopes coming out of the earth. Looked at from the outside, the success of a designer of some well-known machine may appear to be a source of great joy. Sometimes this truly is the case, but usually the amount of trouble, and the restlessness created by the magic supervisors called "competition-ambition," adds enough bitter taste in the cake of fame and success to adjust the matter and protect him from the risk of too much joy and confidence. In this, as well as in many other respects, the life of an active aircraft designer and builder, who is seriously and profoundly attached to his work, is an experience of "higher-ups" and "deeper downs" than would occur in the lives of a vast majority of others. There is a great feeling of joy and satisfaction when a new plane bearing his name achieves something that has never been done before. There is great and profound disappointment when a ship with men on board is lost. It is true that well-built and well-operated modern aircraft is not more dangerous than the average automobile and safety is steadily improved, but this is the result of a feeling of responsibility and permanent tension of many parties connected with this work, one of the first being the responsible designer.

In a brief and final summary of my life's impressions, I believe that I have a greater than average reason to be thankful to destiny for various events and conditions, part of which formed the contents of this book. I am also deeply thankful to this great country of unequalled opportunities which enabled me to resume my life's work and provided the basis for the second part of this book. I doubt if this could have taken place

anywhere else in the world. As for the future results of my personal work, they are unknown. How many more new types of flying ships under the Winged-S will rise in the air after the S-44 Flying Dreadnought is not known. Whatever their number, if any, they will eventually be exceeded and by far surpassed, by other types of greater, faster and more luxurious flying vessels, that will cross the continents and oceans, tropical and polar regions, with remarkable speed, comfort and regularity. Nevertheless, while flying over the longest and most important trans-oceanic airways, they will be following the routes which were originally established and opened for peaceful air travel by the flying Clippers of the Winged-S.